Historic Fire Regimes and Change Since European Settlement on the Northern Mixed Prairie: Effect on Ecosystem Function and Fire Behavior

Final Report

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OVERVIEW OF THE PROBLEM

Wildfires are a common occurrence on the Northern Mixed Prairie. The influence of these fires on the environment is of considerable interest to land managers, wildlife biologists, rangeland ecologists, conservation organizations, and the general public. As extensive areas burn each year across the region, leaving a blackened landscape, concerns are often expressed about the destruction that is observed. Our intent with this study is to sample and record the influences of these fires. We do not place value judgements on these influences; rather, it is left to the various agencies and publics to decide whether the influences of wildfires are negative, positive, or neutral. We believe that this study provides a scientific basis for judgements to be made about suppressing wildfires or allowing them to burn.

Problems of accumulating wildland fuels, both living and dead, during the past half century have increased due to wildland fire management policies and wildland management practices. This is true on rangelands as well as forested lands. Suppression of wildfires has led to an accumulation of fuels that contribute to more intense, often catastrophic, fires that are more difficult to control. Changes have occurred within plant communities, mostly reflected in the plant species present, soil surface protection, and biodiversity. Certain species such as big sagebrush (*Artemisia tridentata*) and junipers (*Juniperus* spp.) have increased in density and distribution, while increasing the woody fuel load on rangelands. Fire suppression has led to encroachment of trees such as ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) onto grasslands. Vegetation structure, a major influence on vegetation suitability for various wildlife species, is potentially altered by wildland fire management policies and practices. Lyon and Smith (2000) suggested that, at the site level, managers need better designed, more comprehensive studies of how fire impacts the quantity and quality of forage.

Build-up of fuels provides an environment for catastrophic wildfires. This is a problem not only in our forests, but also in our rangelands (Gruell et al. 1986). Due to fire suppression and the accumulation of fuels, fires today are more likely to be extreme, difficult to control, and even catastrophic. Consequently, property such as homes, barns, fences, and windmills have been destroyed, and livestock have been killed. Costs and risks of fire control have escalated, risks to human life are high, and fire-dependent ecosystems have deteriorated. It is generally recognized by the Congress, federal and state land management agencies, and the general public that accumulation of wildland fuels must be reduced to reduce human risks and to maintain a healthy, more natural resource.

There is a recognized need to evaluate and compare fuel management practices and methods, including prescribed fire and a "no burn" policy. Needed information includes description or definition of what constitutes a natural fire regime within an ecosystem. Included is a requirement to synthesize available information on historic fire regimes, how fire regimes have changed since European settlement, fire behavior, and how changes affect ecosystem structure and function. This information allows comparisons of recent fire and fuel management practices and predictions of the effects of alternative practices.

Project Objectives:

This research was designed to study historic fire regimes and change since European settlement on the Northern Mixed Prairie, along with effects on ecosystem function and fire behavior. Specific objectives are:

1) To reconstruct the historic fire regimes of the region.

2) To determine changes in fire regimes which have occurred since European settlement, especially during the past half century.

3) To describe the effects of a changing fire regime on the ecosystem, specifically as expressed by changes in plant species, species constancy, vegetation similarity, community diversity, vegetation structure, fuel loading and predicted fire behavior.

4) To describe fire behavior of the historic fire regimes and that of post-European settlement fires.

THE NORTHERN MIXED PRAIRIE

This study encompasses the Northern Mixed Prairie as described by Gould (1968) and Holechek et al. (1998). The Northern Mixed Prairie is that portion of the Great Plains that includes the western half of North and South Dakota, eastern two-thirds of Montana, northeastern one-fourth of Wyoming, southeastern Alberta and southern Saskatchewan (Fig. 1). The region harbors short, mid, and tall grasses, as well as warm and cool season species. Under climax conditions cool-season mid grasses dominate the extensive grasslands. Shrub communities are comprised of extended stands of big sagebrush and silver sagebrush (*Artemisia cana*), mixed shrub types in woody draws and on less-developed soils, and salt-tolerant shrubs on saline soils. Scattered stands of ponderosa pine occur in the central portion of the region.

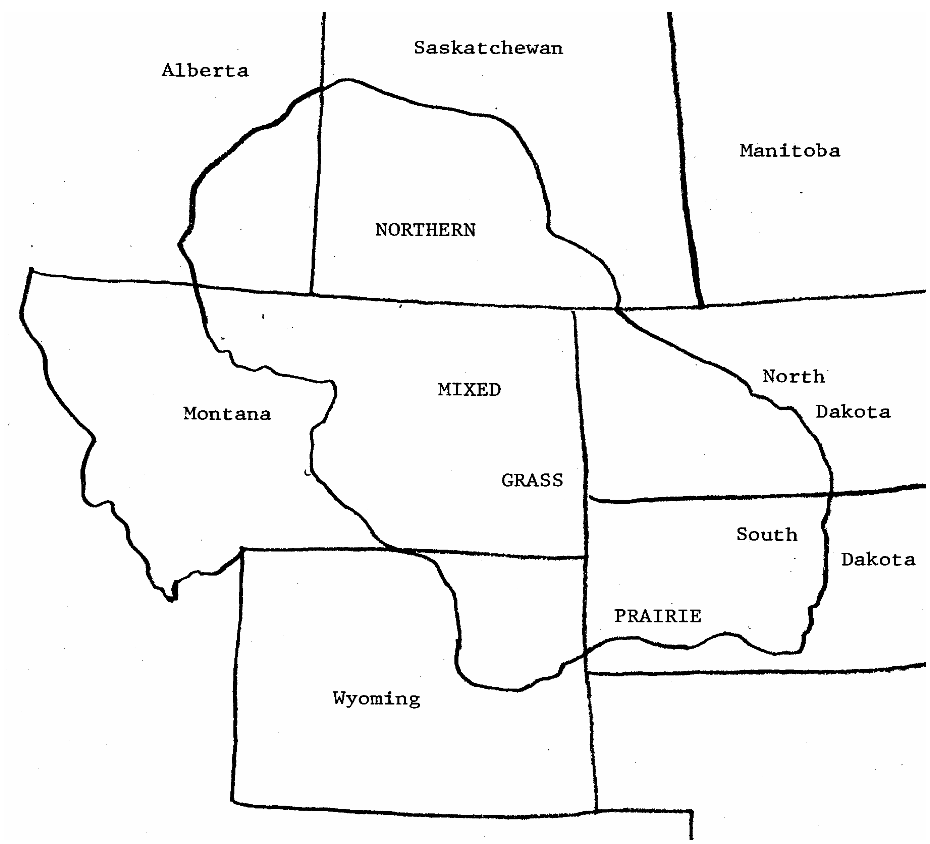


Figure 1. Map of the Northern Mixed Prairie

Topographic Development

The Northern Mixed Prairie has its beginning at the close of the Mesozoic era, about 60 million years ago, as the Cretaceous sea gradually withdrew from the region (Weaver and Albertson 1956). The sea bottom became an extensive plains. It was slowly uplifted, while high mountain ranges, particularly the Rocky Mountains, formed to the west. The topography tilted eastward, creating drainages that flowed in that direction. Over a long period, erosion modified the surface of the plains to form a gently rolling topography interspersed with broad valleys and ridges (Atwood 1940, Weaver and Albertson 1956).

A second period of erosion occurred in which streams deposited fluviatile gravels, sands, and clays from the Rocky Mountains and outlying ranges onto the plains. Heavily loaded streams spread out in a fanlike formation, overflowed their banks, and deposited their loads across the entire area. Numerous braided streams built new bars and shoals and filled in their old channels as they shifted their courses back and forth for miles across the plains (Weaver and Albertson 1956). As the streams moved eastward onto the plains, the streams' capacities were greatly reduced, and the massive loads of debris were deposited as a mantle onto the plains (Atwood 1940). This immense deposition of debris created an almost level plains. Subsequent periods of heavy rainfall rejuvenated the streams, and once again an extensive network of deep channels was cut through the region's surface. During this period modern valleys and riverbeds were wrought, and have in large part carried away the high-level plain of previous stream construction. The end is the Great Plains, which harbors the Northern Mixed Prairie in its west central portion.

Land Surface Form

The Northern Mixed Prairie is characterized by rolling plains. Scattered buttes and plateaus rise from the plains, breaking up the seemingly flat terrain. Coulees and dry valleys give the land more depth, and serve as drainages during flash floods. Isolated mountain ranges dot the area located just east of the Rocky Mountains and become scarce traveling further eastward. As the plains extend further east, the land becomes more rugged. The rolling hills transform into breaks country along the Missouri and Musselshell Rivers in central and eastern Montana. A similar rugged landscape, the badland formations, occurs in western North Dakota along the Little Missouri River and in South Dakota southeast of the Black Hills.

Climate

The climate of the Northern Mixed Prairie is a semi-arid continental regime. This region receives a yearly average of 10-20 inches of rain with great annual fluctuations (Garrison et al. 1977). The majority of precipitation occurs as rain in spring. During summer, precipitation is greatly reduced, evaporation exceeds precipitation, and many plant species complete their life cycle and become semi-dormant. Drought occurs frequently in this region. The rhythmic return of severe drought to this area at about 20-year intervals is well documented (Thomas 1962, Borchert 1971, Perry 1980).

Summer days are hot, while nights are cool. The average frost-free period ranges from less than 100 days in the Canadian region, up to 140 days in the southern portion of the region. The first frost in autumn usually occurs in early September, and the last freeze before the growing season occurs from early May to early June (Holechek et al. 1998). Winters are long and severe, bearing chilling temperatures and strong winds often accompanied by snow. Arctic air moves in from the north, causing periods of extreme cold. Cold periods alternate with milder periods resulting when westerly winds are warmed as they move down the east slope of the Rocky Mountains.

Wind is a dominant climatic factor in the Northern Mixed Prairie. Wind velocities exceed those in most other parts of the country (Weaver and Albertson 1956). Winds prevail in every season. In the winter northerly winds drive blizzards across the region. Chinook winds may also sweep the plains in the late winter and early spring months. Summer winds are hot and dry, evaporating soil surface moisture and leaving the prairie parched and dusty.

Soils

Soils in the region north of the Missouri River are derived from glacial deposits and their associated outwash gravels and sands. Soils are mostly derived from sedimentary materials - primarily sandstone and shale - in the remainder of the region (Sims 1988).

The major soils associated with the Northern Mixed Grass Prairie are in the order Mollisol. Mollisols as described by Holechek et al. (1998) are the natural grassland or prairie soils. They are typically deep and have a high organic matter content with moderate profile development. Entisols and aridisols also occur in this region. These three soil orders are common in the Northern Mixed Prairie, and within these, a range of soil textural classes is found.

Vegetation

The vegetation of an area is mainly controlled by the climate and soils of that region. The origin of the Northern Mixed Prairie dates back about 25 million years ago to the Tertiary Period. During the Eocene, the climate was warm and wet, and a warm temperate forest occupied the Great Plains (Atwood 1940). In the mid Miocene as the Rockies rose, they blocked the moisture-laden winds traveling in from the Pacific, creating a rainshadow over the plains. Increased aridity caused a change in plant species; as the forest disappeared, extensive grasslands evolved across the region (Weaver and Albertson 1956). This vegetation persists today. Climate, paired with natural and aborigine-caused fires, which occurred in sufficient frequency to deter the growth of trees and shrubs on the prairie, is the determinant of the vegetation of the Northern Mixed Prairie (Clements 1916).

Weaver (1954) describes the prairie as a closed community due to the dense network of roots extending several feet deep into the soil. Grasses constitute the majority of the vegetation, but forbs and shrubs are scattered throughout. The Northern Mixed Prairie sustains a high diversity of grass species. It supports mostly short and mid grasses, while tall grasses are present on the most productive sites. Both warm season and cool season grasses are present, but cool season dominate the Northern Mixed Prairie (Holechek et al. 1998). Warm season species mostly occupy a subdominant or invader role. Localized heavy grazing combined with dry cycles in climate favors the short grasses to the extent that they serve as dominants (Weaver and Albertson 1956). The grasses are mainly perennial, long-lived species, with a life span of 10 to 20 years or longer (Weaver 1954). Presence of annual grasses on a site is a distinct sign of disturbance.

Dominant mid grasses include western wheatgrass (*Agropyron smithii*), bluebunch wheatgrass (*Agropyron spicatum*), Kentucky bluegrass (*Poa pratensis*), green needlegrass (*Stipa viridula*), needle-and-thread (*Stipa comata*), and little bluestem (*Schizachyrium scoparium*). Short grasses are represented by prairie Junegrass (*Koeleria cristata*), Sandberg bluegrass (*Poa sandbergii*), blue grama (*Bouteloua gracilis*), buffalograss (*Buchloe dactyloides*), and sideoats grama (*Bouteloua curtipendula*). A few tall grasses are present in isolated stands; the common species are big bluestem (*Andropogon gerardii*), prairie sandreed (*Calamovilfa longifolia*) and switchgrass (*Panicum virgatum*).

MATERIALS AND METHODS

The general approach was to: 1) review and summarize published records concerning historic fire regimes and fire behavior and changes which have occurred since European settlement throughout the Northern Mixed Prairie; 2) review and summarize published records related to the effects of a changing fire regime on the ecosystem; and 3) conduct field studies on a wide array of previously burned sites to obtain additional information about how a changing fire regime affects plant species, species constancy, vegetation similarity, community diversity, vegetation structure, fuel loading and predicted fire behavior.

Field Studies

The ideal study of a wildfire would involve extensive sampling of an area before the fire occurs. The area could then be sampled at various intervals for many years following the fire to record long-term changes. However, we do not know where and when the fires will occur. Time and cost restrictions would also negate such a study. Our contention when we began this research was that previously burned sites can be studied over a short time, and can provide a wealth of information about fire influences. By pairing a burned site with a nearby, unburned site, we can measure site characteristics if the fire had not occurred, and the same characteristics when the site did burn. Results of our study of such paired plots are presented below.

Field studies of previously burned sites were conducted at various locations in Montana, North Dakota and southern Saskatchewan. Initial study sites were on the Charles M. Russell (CMR) National Wildlife Refuge and adjacent Bureau of Land Management (BLM) lands in northeastern Montana. The CMR Fire Management Plan states that since 1964, 312 wildfires have occurred on the CMR or near its boundaries. These fires burned 69,353 acres with an average of 10.1 fires/year. Recorded fires varied from an acre to 11,067 acres in extent. Over

90% of these fires were lightning caused. Recent fire scar data collected on the refuge indicate a fire frequency of 10-20 years prior to the homestead era. The CMR and adjacent BLM lands represent a wide variety of vegetation types, soils and topographic features. Locations, dates and other pertinent information concerning these fires were available at refuge headquarters.

Figure 2. Burned area on the Charles M. Russell National Wildlife Refuge.

Additional study sites were located on BLM lands in the Miles City District in south-eastern Montana; Custer National Forest in southeastern Montana; Northern Cheyenne, Crow, and Fort Belknap Indian Reservations in Montana; U.S. Forest Service Dakota Prairie Grasslands of western North Dakota; Teddy Roosevelt National Park in the Little Missouri badlands of North Dakota; Medicine Lake National Wildlife Refuge in northeastern Montana; Lostwood and Des Lacs National Wildlife Refuges in north-western North Dakota; and Grasslands National Park in southern Saskatchewan. Agency personnel in each contact office provided fire records, locations of previously burned sites, and all other advice and assistance as needed. Study sites were restricted to Federal and state lands because of the availability of records of past fires.

Figure 3. Previously burned grassland within the Northern Mixed Prairie.

Historic Fire Regimes and Fire Behavior

Fire regime is a description of the kind of fire activity that characterizes a specific geographic region (Heinselman 1973). Its elements are 1) fire type and intensity, 2) size of significant fires, and 3) fire intervals for specific land units. Fire behavior is defined as a fire's flame length, forward rate of spread, and fireline intensity as discussed in Albini (1976).

Reconstruction of historic fire regimes and fire behavior involved a review and summary of available information. Published information which provides direct evidence of historic fires was searched, including 1) diaries and reports of early travelers, 2) research reports, especially those that reconstruct fire history from on-site indicators such as tree fire scars, 3) photographic records, including those which compare old photographs to recent "retakes" on the same sites, 4) oral histories of Native Americans, and 5) publications which relate to fire history of the region.

Fire history was also partially reconstructed from indirect evidence of environmental change, mostly change or fluctuation in climate. Climate influences vegetation, which in turn influences fuels. For example, tree-ring studies provide evidence of changes in climate and plant species' distributions related to drought. Studies from the northern Great Plains illustrate the potential for using such data to study drought cycles and related fuel availability within the region. Schumacher (1974) studied tree rings for a 534-year period in North Dakota. He found 17 droughts of 7 years duration or longer. Similar studies over a 750-year period (1220-1952) in Nebraska provide a chronological record of droughts and durations (Champe 1946). These droughts averaged 12.8 years, with an average interval of 23.9 years between droughts. Eight of these droughts averaged 20.6 years, and the longest lasted 38 years. Reports such as these were used to reconstruct regional vegetation, fuels and potential fires.

Changes in Fire Regimes and Fire Behavior Since European Settlement

Reconstruction of fire regimes and fire behavior since European settlement in the Northern Mixed Prairie involved collection and summary of all available information. Documentation of changes included a literature review. Supplemental information was obtained from interviews with agency fire specialists, along with a review of agency records available in field offices. Changes in fire regimes and fire behavior were determined by comparing the historic record with more recent fire regimes and behavior, especially those within the past half- century.

Effects of Changing Fire Regime and Fire Behavior on the Ecosystem

Changes in the fire regime and fire behavior on the ecosystem were assessed from 1) review of pertinent publications, 2) review of unpublished records in field offices, 3) review of plant succession and fuel loading under long-term fire suppression policy and shifts in herbivory, and 4) a supplemental field study to measure actual influences on the ecosystem. We focused on the influence of fire suppression and shifts in herbivory within the Northern Mixed Prairie.

Ecosystem changes addressed in our review of existing information include shifts in major vegetation types, along with changes in plant species, vegetation diversity, vegetation structure, and fuel loading. Supplemental field research assessed effects on plant species, species constancy, vegetation similarity, community diversity, vegetation structure, fuel loading and fire behavior.

Fire records at various field offices were extensively examined, and a representative set of these burned sites was selected for study. Study sites were selected to provide a cross-section of vegetation types and topography burned by wildfires across the study area for which records are available. Each study site was paired with an adjacent unburned site, so that comparisons could be made of burning versus no burning. Paired sites were selected which have the same vegetation type and topographic features.

Field research at each paired site assessed effects of wildfires on average cover values of individual plant species, species constancy, vegetation similarity, community diversity, vegetation structure, fuel loading and fire behavior. Each of these parameters was measured and contrasted within the paired plots.

Plot Establishment and Data Collection

Study plots were selected based on the burned sites available for study and adequate records of each fire. Attempts were made to include as many representative cover (vegetation) types as possible, and to repeat cover types in plot selection. However, certain cover types were much more common than others. A total of 109 paired-plots (one unburned, one burned) within 16 cover types were sampled. These are summarized in Figure 4.

Figure 4. Cover types and number of paired plots sampled within each type for the Northern Mixed Prairie study area.

Code Number	Cover Type	Number of Paired Plots
1	Crested Wheatgrass	1
2	Wheatgrass – Needlegrass	2
3	Wheatgrass – Grama – Needlegrass	23
4	Wheatgrass – Grama	1
5	Wheatgrass	7
6	Big Sagebrush – Grass	22
7	Fescue Grassland	4
8	Mixed Shrub – Grass	16
9	Silver Sagebrush – Grass	11
10	Juniper – Grass	6
11	Greasewood – Grass	3
12	Green Ash – Grass	1
13	Limber Pine – Shrub	2
14	Douglas-Fir – Shrub	2
15	Ponderosa Pine – Shrubland	5
16	Ponderosa Pine – Grassland	3

Note: Cover types were adapted from Shiflet, ed. (1994).

A 1/10-acre macroplot (66 ft. X 66 ft.) was established on each unburned and burned paired site. Within each macroplot, 25 microplots were established in a regular pattern repeated in all plots. Five transects were established in each macroplot, and five microplots were established at 12-foot intervals along each transect. Each microplot is a 10 in. X 20 in. rectangle. Microplot data were recorded on a standardized data form (Appendix 1). Data included a list of all plant species, life form of each, and an estimate of canopy cover class for each species. Canopy cover classes are listed in Appendix 2. Microplots provided data for assessment of plant species cover, species constancy, vegetation similarity, and community diversity. Microplot data were entered into an Excel database, and then analyzed using a SYSTAT statistical package. Statistical analyses were adapted from ECODATA analysis procedures developed by Region 1, U.S. Forest Service (USDA Forest Service 1987).

Figure 5. Recording microplot data within a burned site.

The effect of fire on vegetation and plant species was determined in comparisons of unburned versus burned plot data. Not all cover types were well represented; thus, the comparisons listed in Figure 6 were determined to be appropriate. The following characteristics of vegetation and plant species were assessed: 1) ground and vegetative cover, 2) species canopy cover, 3) species constancy, 4) vegetation similarity, 5) community diversity, 6) vegetative cover, 7) plant canopy cover, 8) influence of fire on range type classification, and 9) influence of fire on vegetation structure.

Figure 6. Cover type comparisons for unburned and burned plots. (Numbers are cover types listed in Fig. 2.)

All grassland and shrubland cover types (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11)
All grasslands (1, 2, 3, 4, 5, 7)
Wheatgrass – Grama – Needlegrass (3)
Wheatgrass (5)
Big Sagebrush – Grass (6)
Mixed Shrub – Grass (8)
Silver Sagebrush – Grass (9)
Juniper – Grass (10)
Conifer (13, 14, 15, 16)

Average Ground Cover

Ground cover characteristics are summarized in percentages from microplot data for bare ground/gravel cover, rock cover, organic cover, basal vegetation cover, woody cover, and litter cover. Vegetative cover is also summarized in percentages from microplot data as tree cover, shrub cover, graminoid cover, and forb cover.

Canopy Cover Values for Plant Species

Average cover values for individual plant species were calculated from microplot cover data. All plant species encountered were included in plot analysis. The hypothesis of no difference in average cover values of individual plant species between an area burned by wildfire and an adjacent unburned area was then tested.

Constancy for Plant Species

Constancy is a synthetic characteristic of a community, rather than a single stand. It is based on species encountered in releves, in this case microplots. Thus, constancy (as defined by Barbour et al. 1980) is the number of microplots within a plot that contain the species, expressed as a percentage. Average constancy values express how evenly the species is distributed throughout the plots and community. The hypothesis of no difference in constancy values of individual plant species between an area burned by wildfire and an adjacent unburned area was then tested.

Vegetation Similarity Values

Vegetation similarity values (100 equals total similarity) will be compared between burned and unburned paired macroplots. These measures of similarity allow one to determine how similar the vegetation is within a microplot and between microplots (in this study, burned versus unburned plots). Within microplot similarity values are of two types: 1) *internal similarity* - calculated as the average similarity among all microplots within a microplot, and 2) *relative similarity* - calculated as the average similarity of plots within a macroplot when compared to a plot representative of that plot. The representative plot is taken from the constancy-average table.

Community Diversity

Community diversity in our study is expressed as 1) Shannon-Wiener index, 2) average number of species, 3) species richness and 4) dominance index. In-depth reviews of diversity and mathematical calculations are provided by Magurran (1988), Peet (1974), and Washington (1984).

The Shannon-Wiener index (Shannon and Wiener 1949) is based on the composition and cover of plant species in a plot. The index varies from 0, for a community of a single species, to values of 7 or more in rich forests such as those of the Siskiyou Mountains in Oregon and California (DeJong 1975). High S-W indices (greater than 1.0) are computed when the plot has high coverages and many species. Shannon-Wiener indices are used as a comparison of diversity among plots. In our study, the indices are used to compare diversity between unburned and burned plots.

The average number of species is a direct method of determining diversity across a plot, and is calculated as the average number of species within subplots. As the average number of species increases, diversity also increases. DeJong (1975) stated that number of species is the single clearest measure of species diversity.

Species richness is simply the number of species present in a community, rather than within subplots. For two completely even communities, the one with the larger number of species will have the higher diversity index. When the data set is a sample of the community, species richness may be underestimated, because rare species may be missed (Hunter 1990).

The average dominance index (a number from 0-100) was developed by the Ecosystem Management Group (USDA Forest Service 1987). The index indicates the degree of dominance by one or more species on a plot. Dominance is simply the fraction of the total canopy cover that is represented by the most common species. Plots with high coverages of one species and low coverages of remaining species tend to generate high dominance indices (near 100.0).

The hypothesis of no difference in vegetation similarity parameters between an area burned by wildfire and an adjacent unburned area was tested.

Vegetative Cover

Vegetative cover was summarized in percentages from microplot data as tree cover, shrub cover, graminoid cover and forb cover.

Plant Canopy Cover

Average cover values for individual plant species were calculated from microplot cover data.

Cover Type Classification in Response to Burning

Cover types are classified based on the vegetation that exists on a site. The vegetation present on a site may approximate that of the original vegetation (climax) or display a multitude of variations due to past management, fire or natural disturbances (Shiflet, ed. 1994). In our study, we classified the cover type of both the unburned site and burned site. A table was developed for each cover type to show the cover type(s) present following burning of the site.

Vegetation Structure

A system for classifying rangeland vegetation structure at various scales was developed by Villnow (1995) for the Interior Columbia River Basin. We modified Villnow's system to produce a dicotomous key (Figure 7) for use in our study. The structural class for each 1/10 ac. macroplot (burned and unburned) was determined to assess the influence of burning on various cover types. The hypothesis of no difference in vegetation structure between an area burned by wildfire and an adjacent unburned area was tested.

Vegetation structure and changes in structure on rangelands are very important as they affect many wildlife species, livestock and various biological processes.

Vegetation structure on rangelands generally includes such attributes as openness, clumpiness, crown differentiation (shrubland types), canopy coverage and other general attributes of both vertical and horizontal structure (Villnow 1995). Literature on rangeland structural classification is sparse.

Determination of initial structure of a grassland or shrubland is critical in determining its potential transition to another state. Tisdale and Hironaka (1981) stated that a natural grassland with closed canopy structure strongly resists shrub invasion. Other ecosystem processes such as nutrient cycling, movement of plant and animal species, and fire are affected by structural attributes on the landscape (McNicoll 1994).

McAuliffe (1988) provides an example of how structure affects small-scale processes such as recruitment in rangelands. He studied the structural effects of a shrubland community in Arizona. Structure (canopy cover and density) of *Ambrosia* sp. was found to affect the recruitment of *Larrea* sp., where 85.5% of all young *Larrea* sp. rooted beneath the canopies of mature *Larrea* sp. plants.

Various species of wildlife are also affected by structure on rangelands. For example, Martin (1970) studied the effects of spraying big sagebrush on sage grouse (*Centrocercus urophasianus*) habitat. He found that sprayed sites with reduced sagebrush cover accounted for 96% of sage grouse occurrences.

Connely et al. (1988) reported that sage grouse quickly take advantage of newly disturbed areas. They suggested that sage grouse leks can be relocated using man-made clearings (changes in structure) where sagebrush cover is nearby.

Lambeth and Hironaka (1982) studied Columbia ground squirrel (*Citellus columbianus*) populations in central Idaho. They found that numbers tend to increase as excessive grazing by domestic sheep causes plant community retrogression on grasslands. Vegetation structure changes from mid-grasses to a lower vertical structure that is preferred by Columbia ground squirrels. They can better observe approaching ground predators where the vertical structure is short.

Kimmis (1987) stated that water yield may be affected by vegetation structure. More soil moisture is allowed to enter the aquifer under a closed grassland canopy than under a shrub canopy. This provides more water downstream from the area. Shrubs can extract water from deeper within the soil, thereby transpiring more water back into the atmosphere. Kimmis also suggested that vegetation structure may also affect the timing of snowmelt and its influence on the hydrological cycle.

Tisdale and Hironaka (1981) found that fuel loading and fire potential are influenced by vegetation structure across a landscape. A grassland with closed canopy structure has a greater fire potential than an open canopy structure.

Influence of fire on structure of grasslands is strongly related to the degree of tolerance of individual grass species to fire. Tisdale and Hironaka (1981) reported that Idaho fescue is less tolerant of fire than are many other grasses, including bluebunch wheatgrass. Yields of Idaho fescue often do not fully return to pre-burn levels for 12 to 15 years. This response is credited to injury of plants and competition from other herbaceous species that often increase following a fire.

Figure 7. Structural classification key for Northern Mixed Prairie. (adapted from Villnow 1995)

1A. Stand has < 10% tree canopy cover	See 2A
1B. Stand has ≥ 10% tree canopy cover	**FOREST TYPE (1)**
2A. Stand has < 10% shrub cover)	See 3A
2B. Stand has ≥ 10% shrub cover	See 4A
3A. Stand has < 20% herbaceous canopy cover	
Stand has < 2% shrub cover	**OPEN HERBLAND (2)**
Stand has 2-9.9% shrub cover	**OPEN HERBLAND/ SCATTERED SHRUB PHASE (2a)**
3B. Stand has ≥ 20% herbaceous canopy cover	
Stand has an insignificant forb component (< 10%)	
Stand has < 2% shrub cover	**CLOSED HERBLAND (3)**
. Stand has 2-9.9% shrub cover	**CLOSED HERBLAND/ SCATTERED SHRUB PHASE (3a)**
Stand has a significant forb component (≥ 10%)	
Stand has < 2% shrub cover	**CLOSED MIXED HERBLAND (4)**
Stand has 2-9.9% shrub cover	**CLOSED MIXED HERBLAND/ SCATTERED SHRUB PHASE (4a)**
4A. Stand has a predominance (≥ 80%) of any one (tall, mid, low) shrub height	See 5A
4B. Stand has a general even distribution of two or more (tall, mid, low) shrub heights	**MIXED SHRUB/MIXED HERBACEOUS (5)**
5A. Stand has a predominance (≥ 80%) of shrubs < 20" tall	See 6A
5B. Stand has a predominance (≥ 80%) of shrubs ≥ 20" tall	See 8A
6A. Stand has < 40% shrub canopy cover	See 7A
6B. Stand has ≥ 40% shrub canopy cover	**CLOSED LOW SHRUB/ MIXED HERBACEOUS (6)**
7A. Stand has < 50% understory of high successional herbs	**OPEN LOW SHRUB/ MIXED HERBACEOUS (7)**
7B. Stand has ≥ 50% understory of high successional herbs	**STABLE LOW SHRUB (8)**
8A. Stand has a predominance (≥ 80%) of shrubs > 20" but ≤ 6.5' tall	See 9A
8B. Stand has a predominance (≥ 80%) of shrubs > 6.5' tall but ≤ 16.5' tall	See 10A
9A. Stand has < 20% shrub canopy coverage	**OPEN MID SHRUB (9)**
9B. Stand has ≥ 20% shrub canopy coverage	**CLOSED MID SHRUB (10)**
10A. Stand has < 20% shrub canopy coverage	**OPEN TALL SHRUB (11)**
10B. Stand has ≥ 20% shrub canopy coverage	**CLOSED TALL SHRUB (12)**

FIRE ON THE NORTHERN MIXED PRAIRIE

Fire, as much or more than any other environmental factor, has helped to shape grasslands and associated woody vegetation. Various investigators have shown that wildfire was a key environmental factor that helped shape plant communities across North America in primeval times (Gruell 1980a, Phillips 1962, Swain 1973, Wellner 1970). Daubenmire (1968) stated that a surprisingly large portion of natural vegetation owes much of its character to the frequency of man-induced fires.

Bragg (1995) stated that fire occurs in any terrestrial ecosystem where there is sufficient dry fuel, an ignition source, and oxygen. Grasslands meet these requirements at certain times of the year. Bragg (1995) suggested that most grasslands would succeed to forests or shrublands without recurring fires.

Figure 8. Wildfire that has helped shape plant communities in breaks topography.

Grasslands of the Great Plains have evolved and survived in a fire-frequented, climatically variable environment over thousands of years (Bragg 1995). Plant species have developed specialized growth forms, reproductive strategies, and seasonal growth patterns that generally allow grassland plants to survive fires. Subterranean buds, rhizomes, bulbs, corms and other specialized structures provide opportunities for plants to renew top growth following a fire. Many plant species that failed to adapt to fire have surely disappeared from these grasslands. Other plant species such as big sagebrush and Rocky Mountain juniper (*Juniperus scopulorum*) have survived periodic burning of grasslands by growing on shallow soils, steep slopes, rocky buttes and highly eroded badlands.

Ignition and flammability are accentuated in grasslands due to topography, combustible materials and low humidity, often coupled with high winds (Kucera 1981). Grassland fuels dry quickly with soil moisture depletion. Fuels accumulate during periods of average to above-average precipitation. During periods of prolonged drought, these fuels are highly combustible. Thunderstorm activity during drought is often characterized by numerous lightning downstrikes and little precipitation (Kucera 1981).

Grasslands that receive greater annual precipitation generally have a higher fire frequency than areas with less moisture (Madden et al. 1999). Grasslands in regions of higher precipitation produce more biomass and litter each year, providing more opportunities for fire to occur. In more arid grasslands, a longer time is required for sufficient fuel to accumulate to carry a fire across the landscape. Thus, arid grasslands have lower fire frequency and are less fire dependent.

Fires in grasslands serve to maintain these grasslands (Bragg 1995, Madden et al. 1999, Higgins 1986, Rowe 1969, Sieg 1998). (Madden et al. 1999) reported that repeated fire causes a decrease in shrub coverage, litter, and vegetation height and density on Northern Mixed Prairie in North Dakota. However, the cover of graminoid species and percentage of live vegetation were increased. Fire suppression has been attributed to the increase and encroachment of woody species such as big sagebrush, ponderosa pine and Douglas-fir into grasslands. Fire is considered important in stabilizing the advance of aspen woodlands into prairies of western Canada (Kucera 1981).

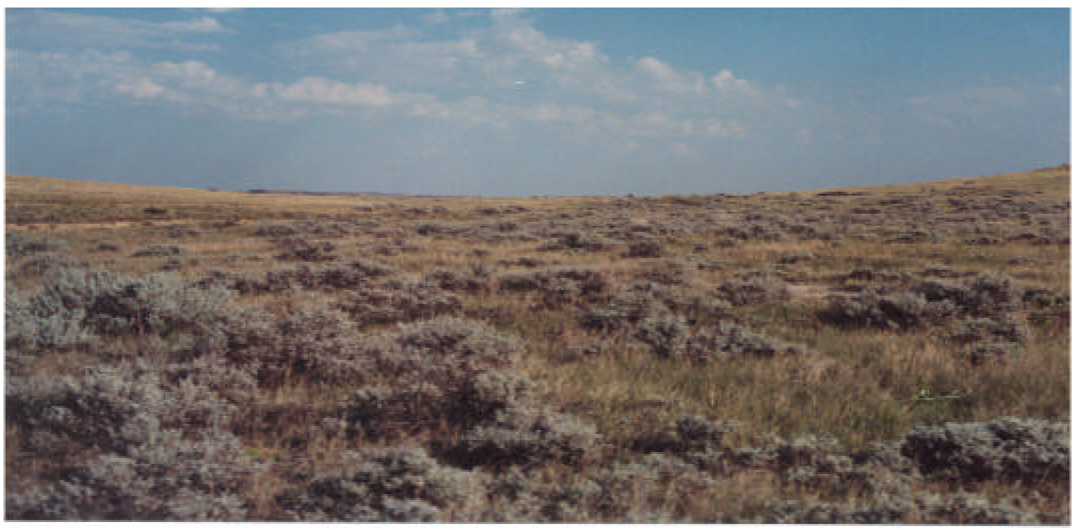


Figure 9. Fine fuel accumulation and dry conditions place big sagebrush stand at risk.

Prehistorical Fires

Nelson and England (1971) reviewed the causes and effects of fire in the northern grassland area of Canada and the nearby United States for the period 1750 to 1900. They concluded that fires were mostly set by native people and lightning on pristine grasslands. Fires were reported to “rage quickly and dramatically over hundreds or thousands of square miles, crossing major river valleys in the process”. Stewart (1953) contended that all grasslands occurring on deep, fertile soil are man-made. He expressed an opinion that the Great Plains grasslands would be covered with grass and trees without the fires set by the Indians.

The pre-historic fire regime of grasslands is difficult to reconstruct (Nelson and England 1971). Unlike woody plants, grasses and forbs do not provide fire scars, growth ring patterns and age structure. Above-ground tissue of herbaceous plants generally dies at the end of each growing season, leaving below-ground live tissue to regenerate the top. Thus, methodologies for documenting prehistorical fire regimes on grasslands are limited. Most of the evidence has relied on written and oral accounts of early travelers across the Northern Mixed Prairie. However, historical accounts vary in detail and language. Only a few of these early travelers documented fires and previously burned grasslands. Travel of early explorers was mostly limited to certain seasons and passages (Higgins 1986).

Archaeological evidence suggests fire was significant in maintaining and expanding Northern Mixed Prairie grasslands. This includes both lightning caused fires and fires ignited by man (Kucera 1981, Jackson 1965).

Fire Intervals

Under pristine conditions, grasslands burned on a regular basis. Barker and Whitman (1988) reported that northern prairies were capable of burning about every 5-7 years. They stated that aspen and balsam poplar (*Populus balsamifera*) in Alberta have increased with fire suppression.

Wright and Bailey (1980) reviewed research on fire ecology and prescribed burning in the Northern Mixed Prairie. They reported that fires were common in pristine grasslands. Extensive fires usually occurred during drought years following 1-3 years of above-average rainfall, which provided abundant and continuous fuel. Fire frequency was probably 5-10 years in the level-to-rolling topography as evidenced by fire frequency from adjoining forests. Frequency of fire increased to 20-30 years when topography is more dissected with breaks and rivers (Sieg 1998). Higgins (1984) found the frequency of lightning-caused fires in mixed-prairie grasslands of North Dakota ranged from 6/year/10,000 km^2 to 24.7/year/10,000 km^2.

Brown and Sieg (1999) studied fire intervals at the ponderosa pine – prairie ecotone in the Black Hills of South Dakota. They reported that fire intervals at the savanna sites were between 10 to 12 years. Chronology studies indicated that regular fire events were common in the 1500s up to the late 1800s or early 1900s, at which time the spreading fires ceased. Fire scars on trees were much less common during the twentieth century. Frost (1998) reported that presettlement fires in this region occurred every 7-12 years.

Madden (1980) stated that fire frequency probably averaged 6 years in the Northern Mixed Prairie, but up to every 25 years in the dry western part of the region. These conclusions were based on rates of fuel accumulation and woody plant invasion.

Indian-Set Fires

Indian-set fires were apparently important in shaping the vegetation encountered by early European travelers throughout the northwestern United States and western Canada. Lewis (1980) presented considerable evidence that the hunter-gatherer native societies often fired the coniferous forests and fire-maintained prairies in early spring to reduce trees and brush while encouraging a diverse mosaic of herbaceous vegetation. In numerous interviews with Indians, he was able to establish that many prairies and meadows were burned annually to discourage encroachment of woody species. Often, only a few very large trees survived the fires.

Reasons for burning by Indians included "the need for horse pasturage, the opening up of sloughs, the establishment of seasonal camp sites, the attraction of greater numbers of game"

(Lewis 1982). Lewis speculated that the tradition of burning probably dates back to the movement of Paleo-Indians northward approximately 8,500 years ago. Barrett (1980) interviewed descendants of early Indians and white homesteaders. From these interviews and a review of historic journals, he concluded that Indians used fire extensively before the 1880s.

George Catlin (1891) spent several years among the Indian tribes of the present states of North Dakota and Montana. His graphic description of fires on the northern Great Plains includes the following:

> *"The prairies burning form some of the most beautiful scenes that are to be witnessed in this country, and also some of the most sublime. Every acre of these vast prairies (being covered for hundreds and hundreds of miles, with a crop of grass, which dies and dries in the fall) burns over during the fall or early in the spring, leaving the ground of a black doleful color."*
>
> *"But there is yet another character of burning prairies, that requires another Letter, and a different pen to describe - the war, or hell of fires! where the grass is seven or eight feet high, as is often the case for many miles together, on the Missouri bottoms; and the flames are driven forward by the hurricanes, which often sweep over the vast prairies of this denuded country. There are many of these meadows on the Missouri, the Platte, and the Arkansas, of many miles in breadth, which are perfectly level, with a waving grass, so high, that we are obliged to stand erect in our stirrups, in order to look over its waving tops as we are riding through it. The fire in these, before such a wind, travels at an immense and frightful rate, and often destroys, on their fleetest horses, parties of Indians, who are so unlucky as to be overtaken by it ..."*

Clues relative to use of fire by Indians prior to 1800 are limited. Acquisition of horses after 1700 by Indians in the region may have led to increased use of fire (Roe 1955), which was often set to improve forage for the animals (Barrett 1980, Lewis 1982).

Lightning-Set Fires

Lightning is considered the major natural cause of ignition throughout the world (Vazquez and Moreno 1998). It is the main cause of fire ignition in the boreal forest (Nash and Johnson 1996) and forest fires in the northern Rocky Mountains (Marsden 1982). However, Higgins (1986) stated that lightning-caused fires were less frequent than those set by humans on the Northern Mixed Prairie.

Lightning is a product of climate. Climate patterns have been unchanged throughout the Northern Mixed Prairie for the last few centuries. Therefore, recent patterns should mimic historic patterns. Most lightning-caused fires occur during the summer and early fall. Bragg (1995) suggested that lightning ignitions were probably common during these times, basing this conclusion on an average of 40 lightning storms that currently occur between May and September. Seventy-five percent of these lightning storms occur during July and August and many are assumed to have caused ignition in grasslands. Higgins (1984) found that 73 percent of lightning-caused fires occurred in July and August. Rowe (1969) observed similar patterns in Saskatchewan grasslands.

Grazing and Fire

Grazing by native ungulates and rodents would have influenced the natural fire regime by reducing fuel buildup. Large herds of bison, elk, and antelope grazed throughout the Northern Mixed Prairie. Perhaps no native herbivore has played a more important role on rangelands than the American bison. Ancestral bison ranged as far east as Florida and as far south as Honduras and Nicaragua in Central America (Dary 1974). Seton (1929) estimated that there were approximately 40 to 60 million bison in North America before European settlement.

England and DeVos (1967) reviewed historical documents relative to the influence of animals, particularly bison, on pristine Canadian grasslands. The documents cover the period 1690 to 1880. This period was selected because of the availability of journals and diaries of early travelers, and the relative absence of disturbance by ranching, sod-busting and settlement by non-native peoples. Inferences to overgrazing by bison are frequently drawn from comments about considerable bison numbers and poor pasturage for horses. Larson (1940) presented an argument that heavy bison grazing and other grazing animals maintained the western plains in a short grass stage.

Johnston (1970) reported that the bison in western Canada were reduced in numbers and range until, in 1879, the last of the animals were driven by prairie fires into Montana. With the exit of bison, these Canadian grasslands were essentially ungrazed until livestock were introduced around 1919-1920. During this 40-year period, the prairies "produced a cover of grass the like of which had never been seen before and which will never be seen again".

Black-tailed prairie dogs were once one of the most numerous and widespread herbivores on the Great Plains of North America (Coppock et al. 1983). Seton (1929) estimated there were 5 billion black-tailed prairie dogs during the nineteenth century. It is estimated that 100 prairie dogs daily consume as much forage as 1 bison; therefore, black-tailed prairie dogs consumed as much forage as 50 million bison. The prairie dog ranged over most of the Great Plains from southern Canada through Texas into Mexico (Osborn and Allan 1949, Bonham and Lerwick 1976). Prairie dog colonies ("towns") covered vast expanses of rangeland. One colony in Texas covered an estimated 25,000square miles (160 mi X 160 mi)(Merriam 1902).

Prairie dogs not only eat plant material, but also clip herbaceous and shrubby vegetation to maintain vigil against ground predators. With reduction of prairie dog populations to less than 2% of their former numbers (Coppock et al. 1983), fuel has increased on these areas.

The seasonal migration of bison was most likely cyclical because of the somewhat constant climate over hundreds of years. Bison show a strong preference for areas with younger vegetation following fire and grazing (Biondini et al. 1999). The crude protein of forage increases under moderate grazing. Forage quality and bison selection of burned areas are prolonged by grazing (Biondini et al. 1999). Bison congregate in burned areas; this grazing prolongs their stay, and helps to create the mosaic of vegetation that is the Northern Mixed Prairie.

Fires Following European Settlement

Gruell (1980b) studied photographic records (1872-1942 and 1968-1972 retakes) of vegetation on the Bridger-Teton National Forest in Wyoming. With few exceptions, big sagebrush is much denser and widespread at present. He reported that "charcoal in the soil and burned material on the surface indicate that this resulted from wildfires that periodically swept sagebrush communities". Big sagebrush is a nonsprouter and is readily killed by fire (Blaisdell 1953).

Nelson and England (1971) reviewed fire effects in the northern Great Plains from 1750-1900. They concluded that lightning and early man commonly set historic fires. Entrance of European settlers into the region strongly influenced the fire regime. New sources of ignition included firing the prairie to locate buffalo bones, spark from iron horseshoes, and sparks thrown from railroad engines. These Europeans purposely and accidentally set fires as they settled the region. Modern man has further altered the influences of fire. Wildfires are often suppressed, litter accumulates to unnaturally high amounts, and accidental fires are often more severe and destructive than recurring natural fires.

Higgins (1986) provided an extensive review of historic fire accounts in the northern Great Plains. He reported that Indian-set fires were far more common than lightning-caused fires. Information about fire frequencies was limited.

Gruell et al. (1986) reported that Douglas-fir and other conifers following fire suppression have invaded several million acres of seral grasslands in Montana. They summarized fuel characteristics and possibilities for fuel modification in these stands.

Historic records of fires in the Northern Mixed Prairie are limited (Higgins 1986). However, fire suppression since the early 1900s has led to changes in the structure and plant species composition in many communities, particularly within those where fire frequency has increased (Daubenmire 1968; Wells 1970, Gartner and White 1986). Bradley and Wallis (1996) stated that "in the 1900s, suppression of fire by modern society has resulted in a significant decrease in the size and occurrence of burned patches on the prairie".

Fire severity within the Northern Mixed Prairie has generally increased and fire frequency has generally decreased over the past 125 years. Changes are attributed to fire prevention and suppression, along with changes in fuels due to livestock grazing. Livestock grazing tends to reduce fine fuel on grasslands. Excessive grazing does not generally lead to massive invasion of annual grasses such as cheatgrass. These altered fire regimes have been largely responsible for more heterogeneous rangeland landscapes, as fires are suppressed before they spread across the large regions as reported with historic fires (Nelson and England 1971). Small, intense fires tend to alter vegetation within the larger, unburned regions.

EFFECTS OF FIRE ON GROUND COVER

Ground cover is important in control of soil erosion. It is also important in holding rainfall and snow on the site, allowing the moisture to enter the soil. Average ground cover values are presented in Tables 1-9. Data were grouped by year-classes to provide an insight into changes over time following a fire. In some comparisons, sufficient data were available to provide for four classes (1-2, 3-5, 6-10, and > 10 years postfire). In other comparisons, year classes were fewer or not feasible, depending on available data.

Combined Grassland and Shrubland Cover Types

We first grouped all grassland and shrubland cover types (Table 1), which are the rangeland types. Average percent bare ground/gravel cover values were higher on burned sites than on unburned sites for longer than 10 years following a fire. Values on unburned sites ranged from 3.1% to 6.8%. On burned sites, cover values were highest (13.7%) on 1-2 year-old burns, and declined to 4.1% on the oldest burns.

Organic and litter cover were immediately reduced by burning, but were mostly restored 6-10 years postfire. On the oldest burns, organic cover values were 28.2% on burned sites and 29.2% on unburned sites.

Basal vegetation, those parts of the plant at the ground level, was essentially the same on burned sites and unburned sites (2.5% vs. 2.6%) 1-2 years after the fire. These values indicate that few of the existing plants were killed by the fire, or were partially replaced by new plants being established.

Table 1. Average ground cover values (%) for combined grassland and shrub cover types On unburned and burned sites following wildfires.

Ages after burned	1-2 years (n = 15)		3-5 years (n = 29)		6-10 years (n = 23)		> 10 years (n = 30)	
	Unburned	vs.Burned	Unburned	vs.Burned	Unburned	vs.Burned	Unburned	vs.Burned
	μ ± SE	μ ± SE	μ ± SE	μ ± SE	μ ± SE	μ ± SE	μ ± SE	μ ± SE
Bare ground/gravel cover	3.1 ± 1.0	13.7 ± 2.6	5.2 ± 1.0	10.7 ± 1.6	6.8 ± 1.5	8.5 ± 1.3	4.1 ± 0.8	5.6 ± 1.0
Rock cover	0.1 ± 0.1	0.2 ± 0.1	0.3 ± 0.1	0.2 ± 0.1	0.1 ± 0.1	0.2 ± 0.1	0.1 ± 0.0	0.1 ± 0.1
Organic cover	36.0 ± 5.9	25.7 ± 6.5	34.0 ± 2.9	28.8 ± 2.5	32.3 ± 3.1	30.4 ± 1.6	34.9 ± 2.3	32.9 ± 3.7
Basal vegetation cover	2.6 ± 0.7	2.5 ± 0.7	3.0 ± 0.4	2.8 ± 0.5	2.3 ± 0.4	2.9 ± 0.6	2.1 ± 0.3	2.2 ± 0.3
Woody cover	0.3 ± 0.2	0.3 ± 0.2	0.5 ± 0.2	0.4 ± 0.2	0.7 ± 0.2	1.2 ± 0.5	1.0 ± 0.2	1.3 ± 0.3
Litter cover	26.1± 3.2	17.9 ± 2.7	28.5 ± 1.5	13.7 ± 2.6	27.1 ± 1.5	24.5 ± 1.8	29.2 ± 1.3	28.2 ± 1.3

Table 2. Average ground cover values for grassland cover types on unburned and burned sites following wildfires.

Ages after burned	1-2 years (n = 9)		3-5 years (n = 12)		6-10 years (n = 7)		> 10 years (n = 10)	
	Unburned	vs.Burned	Unburned	vs.Burned	Unburned	vs.Burned	Unburned	vs.Burned
	μ ± SE	μ ± SE	μ ± SE	μ ± SE	μ ± SE	μ ± SE	μ ± SE	μ ± SE
Bare ground/gravel cover	2.4 ± 1.0	9.8 ± 4.1	3.6 ± 1.0	12.8 ± 3.9	5.6 ± 2.5	7.4 ± 2.0	4.9 ± 1.4	6.1 ± 2.1
Rock cover	0.1 ± 0.1	0.2 ± 0.1	0.3 ± 0.1	0.2 ± 0.1	0.1 ± 0.1	0.2 ± 0.1	0.1 ± 0.0	0.1 ± 0.1
Organic cover	37.0 ± 11.8	30.3 ± 12.4	35.7 ± 6.6	26.6 ± 5.7	34.4 ± 3.6	32.2 ± 6.7	34.7 ± 5.1	32.8 ± 5.8
Basal vegetation cover	4.3 ± 1.1	3.4 ± 1.2	3.4 ± 0.9	2.8 ± 0.7	3.5 ± 0.7	3.8 ± 1.0	3.0 ± 0.7	3.0 ± 0.7
Woody cover	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.3	0.1 ± 0.1	0.0 ± 0.0	1.3 ± 0.9	0.5 ± 0.2	0.8 ± 0.4
Litter cover	20.6± 5.2	15.9 ± 4.9	28.5 ± 3.0	22.1 ± 3.5	29.3 ± 2.0	24.0 ± 2.8	27.8 ± 2.3	25.3 ± 2.4

Ground cover characteristics indicate that soil surface protection was reduced on these rangelands for at least 5 years following a fire. Full recovery was attained after at least 10 years.

Grassland Cover Types

Ground cover summaries for grasslands are shown in Table 2. Burned sites on grasslands had greater percentages of bare ground/gravel cover throughout all ages of burns. Values on unburned sites ranged from 2.4% to 5.6%. On burned sites, cover values were highest (9.8% to 12.8%) through the first five years postfire, then declined to 6.1% on burns older than 10 years.

Organic and litter cover were immediately reduced by burning, but were mostly restored on burned sites >10 years old. On the oldest burns, organic cover values were 27.8% on burned sites and 25.3% on unburned sites.

Basal vegetation was somewhat reduced on burned sites 1-2 years after the fire, and remained lower that that on unburned sites through the first five years. These cover values fully recovered during the 6-10 year period. These values indicate that the fire killed some of the existing plants, and that a few years were required for plants to become re-established.

Ground cover characteristics indicate that soil surface protection was reduced on these rangelands for at least 5 years following a fire. Full recovery was not attained after 10 years following the fire

Wheatgrass –Grama – Needlegrass Cover Type

Burned sites for this cover type were grouped into 1-5 years and >5 years postburn. Burned sites had greater percentages of bare ground/gravel cover for the first 5 years following the fire, but had recovered after 5 years (Table 3). Values on unburned sites ranged from 2.7%

to 4.6%. On burned sites, cover values were 9.5% during the first 5 years, but had recovered to 4.3% after 5 years.

Organic and litter cover were somewhat reduced by burning, but were fully restored after 5 years. Basal vegetation was somewhat reduced on burned sites during the first 5 years after the fire, but had also fully recovered after five years.

Ground cover characteristics indicate that soil surface protection was reduced on these rangelands for at least 5 years following a fire. Full recovery was reached after 5 years.

Wheatgrass Cover Type

Limited numbers of paired plots in the Wheatgrass cover type required that all burned sites be grouped together (Table 4). Thus, the comparison is burned versus unburned sites. Burned sites had greater percentages of bare ground/gravel cover (15.3%) compared to unburned (5.6%). Burning also reduced organic cover, basal vegetation cover, and litter cover. The limited number of wildfires sampled in the Wheatgrass cover type do not allow us to determine how many years are required for full recovery of ground cover.

Big Sagebrush – Grass Cover Type

Burned sites for this cover type were grouped into 1-5 years and >5 years postburn. Burned sites had greater percentages of bare ground/gravel cover for in all comparisons, but most recovered after 5 years (Table 5). Values on unburned sites ranged from 7.6% to 7.8%. On burned sites, cover values were 14.9% during the first 5 years, but had recovered to 8.5% after 5 years.

Table 3. Average ground cover values for Wheatgrass-Grama-Needlegrass cover type on unburned and burned sites following wildfires.

Ages after burned	1-5 years (n = 14)		> 5 years (n = 9)	
	Unburned vs.Burned		Unburned vs.Burned	
	μ ± SE	μ ± SE	μ ± SE	μ ± SE
Ground Cover				
Bare ground/gravel cover (%)	2.7 ± 0.7	9.5 ± 2.7	4.6 ± 2.5	4.3 ± 1.4
Rock cover (%)	0.2 ± 0.2	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0
Organic cover (%)	36.7 ± 7.5	30.1 ± 7.3	35.3 ± 5.5	36.0 ± 7.6
Basal vegetation cover (%)	4.2 ± 0.8	3.1 ± 0.8	4.0 ± 0.6	4.4 ± 0.8
Woody cover (%)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.1
Litter cover(%)	24.5± 3.3	20.4 ± 3.1	24.7 ± 2.5	24.1 ± 3.0

Table 4. Average ground cover values for Wheatgrass cover type on unburned and burned sites following wildfires.

Ages after burned	All Ages (n = 7)	
	Unburned vs.Burned	
	μ ± SE	μ ± SE
Ground Cover		
Bare ground/gravel cover (%)	5.6 ± 1.8	15.3 ± 5.6
Rock cover (%)	0.1 ± 0.1	0.5 ± 0.5
Organic cover (%)	33.6 ± 4.4	22.4 ± 4.9
Basal vegetation cover (%)	1.7 ± 0.6	1.2 ± 0.4
Woody cover (%)	1.0 ± 0.4	2.1 ± 1.1
Litter cover(%)	30.3± 2.4	21.4 ± 4.5

Organic and litter cover were somewhat reduced by burning, but were fully restored after 5 years. Basal vegetation was not reduced during the first 5 years after the fire, and increased to almost twice that of unburned sites after 5 years. Fires substantially reduced big sagebrush, allowing herbaceous species to increase on burned sites. This would account for the greater percentage of basal vegetation.

Ground cover characteristics indicate that soil surface protection was reduced on these rangelands for at least 5 years following a fire. Full recovery was reached after 5 years.

Silver Sagebrush – Grass Cover Type

Limited numbers of paired plots in the Silver Sagebrush - Grass cover type required that all burned sites be grouped together (Table 6). Thus, the comparison is burned versus unburned sites. No differences were found in ground cover characteristics between burned and unburned sites.

Juniper – Grass Cover Type

Limited numbers of paired plots in the Juniper – Grass cover type required that all burned sites be grouped together (Table 7). Thus, the comparison is burned versus unburned sites. Burned sites had greater percentages of bare ground/gravel cover (10.4%) compared to unburned (3.7%). Burning also reduced organic cover and litter cover. Percentage basal vegetation cover was less than 1% on both unburned and burned sites.

Wildfires in this cover type are common. We visited a number of burned areas that were not included in our study, because comparable unburned/burned paired plots were not available. The limited number of wildfires in the Juniper – Grass cover type do not allow us to determine how many years are required for full recovery of ground cover. However, this cover type mostly occurs in “breaks” terrain; vegetative regrowth on burned sites will be slow, slowing the accumulation of organic cover and litter cover on the soil surface.

Table 5. Average ground cover values for Big Sagebrush – Grass cover type on unburned and burned sites following wildfires.

Ages after burned	1-5 years (n = 14)		> 5 years (n = 9)	
	Unburned vs.	Burned	Unburned vs.	Burned
Ground Cover	μ ± SE	μ ± SE	μ ± SE	μ ± SE
Bare ground/gravel cover (%)	7.8 ± 1.8	14.9 ± 2.1	7.6 ± 2.1	8.5 ± 2.0
Rock cover (%)	0.5 ± 0.2	0.4 ± 0.2	0.2 ± 0.2	0.3 ± 0.2
Organic cover (%)	31.1 ± 4.3	25.2 ± 2.8	30.4 ± 4.8	30.8 ± 4.5
Basal vegetation cover (%)	2.2 ± 0.3	2.4 ± 0.6	1.4 ± 0.2	2.7 ± 0.7
Woody cover (%)	0.4 ± 0.1	0.3 ± 0.1	1.5 ± 0.3	0.3 ± 0.2
Litter cover(%)	25.0 ± 2.3	22.0 ± 2.0	23.3 ± 2.1	25.7 ± 2.8

Table 6. Average ground cover values for Silver Sagebrush – Grass cover type on unburned and burned sites following wildfires.

Ages after burned	All Ages (n = 11)	
	Unburned vs.	Burned
Ground Cover	μ ± SE	μ ± SE
Bare ground/gravel cover (%)	5.9 ± 1.1	6.0 ± 1.5
Rock cover (%)	0.0 ± 0.0	0.1 ± 0.1
Organic cover (%)	33.8 ± 3.8	33.8 ± 4.3
Basal vegetation cover (%)	3.1 ± 0.5	3.7 ± 0.5
Woody cover (%)	0.3 ± 0.1	0.1 ± 0.1
Litter cover(%)	28.5 ± 1.9	28.0 ± 2.3

Mixed Shrub – Grass Cover Type

Burned sites for this cover type were grouped into 1-10 years and >10 years postburn. Burned sites had greater percentages of bare ground/gravel cover, organic cover, and litter cover in all comparisons (Table 8). Basal vegetative cover was fully recovered 1-10 years after the fire.

Ground cover characteristics indicate that soil surface protection was reduced on The Mixed Shrub – Grass cover type for the first 10 years. Soil protection was not fully recovered after 10 years postfire.

Conifer Cover Types

Limited numbers of paired plots in the Conifer cover types required that all burned sites be grouped together (Table 9). Conifer cover types include the Limber Pine – Shrub, Douglas-Fir – Shrub, Ponderosa Pine – Shrubland, and Ponderosa Pine – Grassland. Thus, the comparison is burned versus unburned sites of all conifer cover types. Burned sites had greater percentages of bare ground/gravel cover (5.0%) compared to unburned (10.2%). Burning also reduced organic cover and litter cover. Basal vegetative cover was slightly greater on burned sites.

Table 7. Average ground cover values for Juniper – Grass cover type on unburned and burned sites following wildfires.

Ages after burned	All Ages (n = 6)	
	Unburned vs. Burned	
Ground Cover	μ ± SE	μ ± SE
Bare ground/gravel cover (%)	3.7 ± 1.7	10.4 ± 2.6
Rock cover (%)	0.0 ± 0.0	0.2 ± 0.1
Organic cover (%)	34.6 ± 2.0	26.3 ± 3.4
Basal vegetation cover (%)	0.6 ± 0.2	0.4 ± 0.2
Woody cover (%)	1.6 ± 0.4	3.0 ± 0.6
Litter cover(%)	33.1± 1.9	25.3 ± 2.9

Table 8. Average ground cover values for Mixed Shrub – Grass cover type on unburned and burned sites following wildfires.

Ages after burned	1-10 years (n = 8)		> 10 years (n = 8)	
	Unburned vs. Burned		Unburned vs. Burned	
Ground Cover	μ ± SE	μ ± SE	μ ± SE	μ ± SE
Bare ground/gravel cover (%)	1.0 ± 0.3	9.0 ± 2.6	1.4 ± 0.7	4.5 ± 1.5
Rock cover (%)	0.0 ± 0.0	0.1 ± 0.3	0.2 ± 0.1	0.1 ± 0.0
Organic cover (%)	38.0 ± 3.9	29.8 ± 3.7	36.9 ± 4.1	32.0 ± 2.0
Basal vegetation cover (%)	1.9 ± 1.0	2.1 ± 1.0	1.1 ± 0.3	1.2 ± 0.3
Woody cover (%)	1.3 ± 0.6	1.3 ± 0.7	1.6 ± 0.7	3.0 ± 0.8
Litter cover(%)	34.8± 1.7	27.6 ± 2.4	33.0 ± 2.2	30.6 ± 1.6

Table 9 Average ground cover values for Conifer cover types on unburned and burned sites following wildfires.

Ages after burned	All Ages (n = 11)	
	Unburned vs.	Burned
	μ ± SE	μ ± SE
Ground Cover		
Bare ground/gravel cover (%)	5.0 ± 2.0	10.2 ± 5.3
Rock cover (%)	0.9 ± 0.6	0.9 ± 0.5
Organic cover (%)	32.9 ± 2.7	25.7 ± 4.0
Basal vegetation cover (%)	1.0 ± 0.2	1.5 ± 0.3
Woody cover (%)	1.0 ± 0.3	2.3 ± 0.8
Litter cover(%)	31.4 ± 2.2	23.7 ± 3.4

EFFECT OF FIRE ON INDIVIDUAL PLANT SPECIES

A major concern with wildfires is their influence on the individual plant species that are present on the sites. Basic principles of plant ecology imply that any form of disturbance, including fire, may effect changes in the percentage composition of plant species on the site. One of the objectives of our study was to determine how each species responded to fire; this was accomplished by assessing changes in average canopy cover and constancy of each species.

Canopy Cover

Average canopy cover values are presented in Tables 10-15. Data were grouped by year-classes to provide an insight into changes over time following a fire. In some comparisons, sufficient data were available to provide for four year-classes (1-2, 3-5, 6-10, and > 10 years postfire). In other comparisons, year-classes were fewer or not feasible, depending on available data.

Inclusion of all recorded species in the tables was considered to be undesirable. Many species are represented by occasional individuals; such species provide insufficient data to show trends following a fire. For each of the well-represented cover types, those species present in significant amounts were selected for inclusion in the table for that type. These include those species considered to be important as high successional species, forage species, wildlife foods and cover, and weeds.

Wheatgrass – Grama – Needlegrass Cover Type

Estimates of average canopy cover values of individual plant species on unburned sites, sites 1-5 years postburn, and sites >5 years postburn are presented in Table 10. One shrub, 13 graminoids, and 8 forbs were present in significant amounts to provide information relative to fire effects on individual species.

The only shrub species of any importance within the cover type was fringed sage. This species doubled in average canopy cover for the first 1-5 years postfire, then showed no difference from unburned sites after 5 years.

Response of grasses and sedges to fire varied by species. Of the 13 species present in significant amounts, 7 had lower canopy coverages > 5 years post fire, 5 were about the same, and only prairie Junegrass appears to have increased. Sideoats grama was considerably reduced, buffalograss disappeared from burned sites, and plains muhly almost disappeared. Western wheatgrass canopy cover initially increased after the fire, then was lower than on unburned sites after 5 years. Green needlegrass canopy coverage remained about the same following burning. Needle-and-thread grass slightly decreased in canopy coverage 1-5 years postfire, then further after 5 years.

Big Sagebrush – Grass Cover Type

Estimates of average canopy cover values of individual plant species on unburned sites, sites 1-5 years postburn, and sites >5 years postburn are presented in Table 12. Two shrubs, 8 graminoids, and 10 forbs were present in significant amounts to provide information relative to fire effects on individual species.

Average canopy cover of fringed sage somewhat increased following a fire, while that of big sagebrush was reduced to about one-half that of unburned sites.

Response of grasses and sedges to fire varied by species. Of the 8 species present in significant amounts, 4 had lower average canopy cover values during the first 5 years postfire. These includedbluebunch wheatgrass, Sandberg bluegrass, green needlegrass, and needle-and-thread grass. Green needlegrass and needle-and-thread grass recovered after 5 years, when each had at least twice the average canopy cover of unburned sites. Western wheatgrass was little affected by fire. Blue grama had about twice the canopy cover of unburned sites after 5 years.

Four forbs increased on burned sites during the > 5-year period, 3 species declined, and one remained about the same. Plains pricklypear (*Opuntia polycantha*) was considerably reduced by fire; average canopy cover was 1.1% on unburned sites and 0.1% >5 years postfire.

Wheatgrass Cover Type

Estimates of average canopy cover values of individual plant species on unburned sites versus burned sites are presented in Table 11. Three shrubs, 5 graminoids, and 3 forbs were present in significant amounts to provide information relative to fire effects on individual species.

Burning reduced two shrub species. Rocky Mountain juniper was reduced from 2.9% to 0.1%, while skunkbush sumac (*Rhus trilobata*) was reduced from 0.8% to 0.2% by the fires. Average canopy cover of western snowberry (*Symphoricarpos occidentalis*) appears to have remained the same.

Of the 5 grasses present in significant amounts, western wheatgrass and blue grama average canopy cover values were higher on burned sites. The other grasses had somewhat lower values, but these may not be significant. Sideoats grama average canopy cover was not reduced by fire on this cover type to the extent that it was reduced on the Wheatgrass – Grama – Needlegrass cover type.

Forb species generally remained stable or increased after a fire. Clubmoss was the exception. It declined from an average of 20.3% canopy coverage on unburned plots, to 6.6% in plots > 5 years old. Plains pricklypear was present in small amounts on unburned sites, but was somewhat reduced on burned sites.

Table 10. Average canopy cover values (%, SE) for individual plant species on unburned and burned sites for the Wheatgrass-Grama-Needlegrass cover type.

		Burned Sites	
	Unburned Sites (n = 23)	1-5 Years (n = 14)	≥ 5 Years (n = 9)
Plant Species	μ ± SE	μ ± SE	μ ± SE
Shrubs			
Fringed sage	1.0 ± 0.3	2.0 ± 1.2	0.9 ± 0.5
Grasses and Sedges			
Western wheatgrass	2.6 ± 0.6	4.0 ± 1.3	1.3 ± 0.4
Bluebunch wheatgrass	0.7 ± 0.4	1.0 ± 0.7	0.6
Sideoats grama	10.3 ± 9.2	6.3 ± 5.8	1.3
Blue grama	2.5 ± 0.7	1.6 ± 0.3	1.9 ± 0.6
Japanese brome	0.4 ± 0.2	0.1 ± 0.0	0.7 ± 0.5
Buffalograss	0.9	0.7 ± 0.3	–
Prairie sandreed	0.6 ± 0.3	1.8 ± 1.4	0.5
Threadleaf sedge	1.4 ± 0.3	0.7 ± 0.3	1.1 ± 0.2
Prairie Junegrass	0.7 ± 0.2	0.7 ± 0.3	1.3 ± 0.4
Plains muhly	0.8 ± 0.2	0.4 ± 0.0	0.1
Sandbergbluegrass	0.5 ± 0.3	0.1 ± 0.0	0.4 ± 0.2
Needle-and-thread grass	2.9 ± 0.5	2.7 ± 0.9	1.7 ± 0.6
Green needlegrass	0.8 ± 0.3	0.5 ± 0.2	0.7 ± 0.4
Forbs			
Western yarrow	0.2 ± 0.0	0.3 ± 0.1	0.4 ± 0.3
Rosy pussytoes	0.1 ± 0.0	0.1 ± 0.0	1.1 ± 0.7
Cudweed sagewort	0.5 ± 0.2	0.1 ± 0.1	1.0 ± 0.4
Scarlet beeblossom	0.6 ± 0.1	0.8 ± 0.3	0.3 ± 0.2
Plains pricklypear	1.1 ± 1.0	1.1 ± 0.6	0.1
Hood's phlox	0.4 ± 0.2	0.2 ± 0.1	0.5 ± 0.4
Scarlet globemallow	1.3 ± 0.6	0.9 ± 0.3	–
Round-leafed thermopsis	0.3 ± 0.1	0.3 ± 0.1	1.1 ± 0.7

Table 11. Average canopy cover values (%, SE) for individual plant species on unburned and burned sites for the Wheatgrass cover type.

	Unburned Sites (n = 7)	Burned Sites (n = 7)
Plant Species	μ ± SE	μ ± SE
Shrubs		
Rocky Mountain juniper	2.9 ± 1.1	0.1
Skunkbush sumac	0.8 ± 0.5	0.2 ± 0.2
Western snowberry	0.6 ± 0.4	0.5 ± 0.4
Grasses and Sedges		
Western wheatgrass	1.7 ± 0.7	2.7 ± 0.7
Bluebunch wheatgrass	1.4 ± 0.6	1.0 ± 0.3
Blue grama	0.1 ± 0.0	1.1 ± 0.3
Japanese brome	0.8 ± 0.7	0.6 ± 0.4
Prairie Junegrass	0.4 ± 0.2	0.2 ± 0.1
Forbs		
Western yarrow	0.5 ± 0.2	0.3 ± 0.1
Dandelion	0.5 ± 0.4	0.6 ± 0.3
American vetch	0.1 ± 0.0	0.4 ± 0.2

Table 12. Average canopy cover values (%, SE) for individual plant species on unburned and burned sites for the Big Sagebrush-Grass cover type.

		Burned Sites	
	Unburned Sites (n = 23)	1-5 Years (n = 14)	> 5 Years (n = 9)
Plant Species	µ ± SE	µ ± SE	µ ± SE
Shrubs			
Fringed sage	0.9 ± 0.3	0.6 ± 0.3	1.5 ± 0.7
Big sagebrush	6.4 ± 0.9	3.1 ± 1.3	3.4 ± 1.7
Grasses and Sedges			
Western wheatgrass	2.3 ± 0.2	2.7 ± 0.2	2.5 ± 0.6
Bluebunch wheatgrass	1.4 ± 0.4	0.9 ± 0.5	0.9 ± 0.4
Blue grama	1.3 ± 0.2	1.3 ± 0.3	2.7 ± 0.5
Japanest brome	0.5 ± 0.2	0.7 ± 0.4	0.6 ± 0.4
Prairie Junegrass	1.0 ± 0.2	1.3 ± 0.3	0.6 ± 0.3
Sandberg bluegrass	1.5 ± 0.3	0.9 ± 0.2	1.3 ± 0.5
Needle-and-thread grass	0.9 ± 0.4	0.3 ± 0.1	1.8 ± 0.6
Green needlegrass	0.6 ± 0.3	0.2 ± 0.1	1.5 ± 1.4
Forbs			
Western yarrow	0.6 ± 0.2	0.4 ± 0.2	0.4 ± 0.1
Rosy pussytoes	0.1 ± 0.0	0.1 ± 0.1	0.4 ± 0.3
Yellow sweetclover	1.5 ± 0.7	0.2 ± 0.1	2.4 ± 2.1
Brittle pricklypear	0.2 ± 0.1	0.2 ± 0.1	0.1
Plains pricklypear	0.4 ± 0.1	0.1 ± 0.0	0.2 ± 0.1
Clubmoss	20.3 ± 5.1	4.2 ± 2.3	6.6 ± 2.1
Scarlet globemallow	0.1 ± 0.0	0.3 ± 0.1	0.8 ± 0.7
Dandelion	0.3 ± 0.1	0.2 ± 0.1	0.6 ± 0.3
Yellow salsify	0.1 ± 0.0	0.1 ± 0.0	0.3 ± 0.1
American vetch	0.4 ± 0.1	0.7 ± 0.3	0.4 ± 0.3

Mixed Shrub – Grass Cover Type

Estimates of average canopy cover values of individual plant species on unburned sites, sites 1-10 years postburn, and sites >10 years postburn are presented in Table 13. Six shrubs, 4 graminoids, and 9 forbs were present in significant amounts to provide information relative to fire effects on individual species.

Creeping juniper (*Juniperus horizontalis*) had an average canopy cover value of 6.7% before burning, disappeared from paired plots 1-10 years after the fires, and reappeared with a 4.8% canopy in burned sites >10 years of age. Rocky Mountain juniper had 9.9% average canopy cover in unburned sites, but was not recorded in burned plots of any age. The other shrub species had mostly increased after 10 years when compared to unburned sites. The exception was western snowberry, which increased considerably over unburned sites during the first 10 years, but declined below unburned levels after 10 years postfire.

Response of grasses and sedges to fire varied by species. Western wheatgrass increased during the 10-year period postfire, then declined to a level of unburned sites. Bluebunch wheatgrass was reduced during the first 10 years, then increased to near twice the level of unburned sites afterward. Kentucky bluegrass was reduced by fire.

Forb species varied in their response to fire. Western yarrow (*Achillea millefolium*) and cudweed sagewort (*Artemisia ludoviciana*) increased, Blue lettuce (*Lactuca pulchella*) was present only on burned sites, Canada thistle (*Circium arvense*) declined, while the changes in other forb species are inconclusive.

Silver Sagebrush – Grass Cover Type

Estimates of average canopy cover values of individual plant species on unburned sites versus burned sites are presented in Table 14. Three shrubs, 11 graminoids, and 8 forbs were present in significant amounts to provide information relative to fire effects on individual species.

Burning reduced two shrub species. The percent canopy cover of fringed sage was reduced from 0.9% to 0.4%, while silver sagebrush was reduced from 2.2% to 1.9% by the fires. Average canopy cover of western snowberry was greater on burned sites, increasing from 0.4% to 1.0%.

Of the 11 grasses present in significant amounts, only two showed an increase following a fire. Blue grama average canopy cover values increased from 1.8% to 4.5%, while red threeawn (*Aristida longiseta*) showed a moderate increase. The other grasses were not much affected by fire, although western wheatgrass and bluebunch wheatgrass showed moderate decreased in percent canopy cover.

The significant forb species were mostly unaffected by fire, or somewhat increased. Brittle pricklypear (*Opuntia fragilis*) and plains pricklypear were exceptions. The fires reduced both species.

Juniper – Grass Cover Type

Estimates of average canopy cover values of individual plant species on unburned sites versus burned sites are presented in Table 15. Three shrubs, 5 graminoids, and 6 forbs were present in significant amounts to provide information relative to fire effects on individual species.

Burning reduced two shrub species. The percent canopy cover of Rocky Mountain juniper was reduced from 6.4% to 0.2%, while skunkbush sumac was reduced from 0.4% to 0.1% by the fires. Average canopy cover of western snowberry was unaffected by burning.

Of the 5 grasses present in significant amounts, only two showed an increase following a fire. Average canopy cover values of western wheatgrass increased from 1.0% to 1.4%, while Japanese brome increased from 0.9% to 1.9%. The other grasses were not much affected by fire.

The significant forb species mostly increased on burned sites. Round-leafed thermopsis (*Thermopsis rhombifolia*) was not recorded on unburned sites, but averaged 0.4% canopy cover on paired burned sites.

Table 13. Average canopy cover values (%, SE) for individual plant species on unburned and burned sites for the Mixed Shrub-Grass cover type.

		Burned Sites	
	Unburned Sites (n = 18)	1-10 Years (n = 8)	> 10 Years (n = 8)
Plant Species	μ ± SE	μ ± SE	μ ± SE
Shrubs			
Creeping juniper	6.7 ± 6.3	_	4.8 ± 4.7
Rocky Mountain juniper	9.9 ± 3.3	_	_
Chokecherry	3.5 ± 1.4	0.9 ± 0.7	6.3 ± 3.1
Skunkbush sumac	0.3 ± 0.1	0.7 ± 0.6	0.7 ± 0.2
Rose	1.1 ± 0.3	1.1 ± 0.2	1.3 ± 0.6
Western snowberry	10.3 ± 3.7	18.2 ± 6.4	2.7 ± 1.0
Grasses and Sedges			
Western wheatgrass	0.5 ± 0.4	1.3 ± 0.6	0.6 ± 0.2
Bluebunch wheatgrass	0.6 ± 0.2	0.1 ± 0.1	1.3 ± 0.3
Japanese brome	1.0 ± 0.2	1.0 ± 0.4	0.4 ± 0.2
Kentucky bluegrass	1.7 ± 0.7	1.1 ± 0.5	0.7 ± 0.5
Forbs			
Western yarrow	0.4 ± 0.1	0.9 ± 0.2	0.7 ± 0.3
Cudweed sagewort	0.4 ± 0.2	1.2 ± 0.4	1.0 ± 0.3
Canada thistle	6.0 ± 1.6	2.1 ± 1.1	1.2 ± 0.4
Blue lettuce	0.0 ± 0.0	0.3 ± 0.2	0.6 ± 0.2
Prickly lettuce	0.3 ± 0.1	1.3 ± 0.8	0.3 ± 0.2
Goldenrod	0.2 ± 0.1	0.2 ± 0.1	0.6 ± 0.2
Dandelion	0.7 ± 0.3	0.8 ± 0.3	0.3 ± 0.1
Yellow salsify	0.1 ± 0.0	0.3 ± 0.2	0.0 ± 0.0
American vetch	0.3 ± 0.3	0.1 ± 0.0	0.1 ± 0.0

Table 14. Average canopy cover values (%, SE) for individual plant species on unburned and burned sites for the Silver Sagebrush-Grass cover type.

	Unburned Sites (n = 11)	Burned Sites (n = 11)
Plant Species	μ ± SE	μ ± SE
Shrubs		
Silver sagebrush	2.2 ± 0.5	1.9 ± 0.4
Fringed sage	0.9 ± 0.5	0.4 ± 0.2
Western snowberry	0.4 ± 0.4	1.0 ± 0.6
Grasses and Sedges		
Western wheatgrass	2.6 ± 1.5	1.4 ± 0.8
Bluebunch wheatgrass	0.6 ± 0.2	0.4 ± 0.2
Red threeawn	0.9 ± 0.3	1.4 ± 1.0
Blue grama	1.8 ± 0.5	4.5 ± 1.5
Japanese brome	1.1 ± 0.4	1.1 ± 0.3
Prairie sandreed	1.4 ± 0.7	1.5 ± 1.1
Prairie Junegrass	1.1 ± 0.3	0.8 ± 0.4
Kentucky bluegrass	0.2 ± 0.1	0.3 ± 0.1
Sandberg bluegrass	0.8 ± 0.7	0.8 ± 0.4
Needle-and-thread grass	1.2 ± 0.4	1.0 ± 0.3
Green needlegrass	0.8 ± 0.5	0.9 ± 0.3
Forbs		
Western yarrow	0.2 ± 0.1	0.1 ± 0.0
Blanket-flower	0.1 ± 0.0	0.3 ± 0.2
Brittle pricklypear	0.8 ± 0.6	0.2 ± 0.2
Plains pricklypear	0.9 ± 0.4	0.6 ± 0.1
Scarlet globemallow	0.8 ± 0.3	1.3 ± 0.5
Dandelion	0.6 ± 0.5	0.9 ± 0.7
Round-leafed thermopsis	0.2 ± 0.1	0.5 ± 0.2
Yellow salsify	0.5 ± 0.5	0.3 ± 0.2

Table 15. Average canopy cover values (%, SE) for individual plant species on unburned and burned sites for the Juniper-Grass cover type.

Plant Species	Unburned Sites (n = 6) μ ± SE	Burned Sites (n = 6) μ ± SE
Shrubs		
Rocky Mountain juniper	6.4 ± 1.1	0.2 ± 0.0
Skunkbush sumac	0.4 ± 0.3	0.1 ± 0.0
Western snowberry	0.5 ± 0.4	0.4 ± 0.3
Grasses and Sedges		
Western wheatgrass	1.0 ± 0.4	1.4 ± 0.8
Bluebunch wheatgrass	2.0 ± 0.5	2.0 ± 0.3
Japanese brome	0.9 ± 0.7	1.9 ± 0.9
Prairie junegrass	0.2 ± 0.1	0.3 ± 0.1
Green needlegrass	0.6 ± 0.5	0.5 ± 0.3
Forbs		
Western yarrow	0.3 ± 0.1	0.9 ± 0.5
Yellow sweetclover	0.3 ± 0.2	0.8 ± 0.4
Dandelion	0.2 ± 0.2	1.1 ± 0.7
Round-leafed thermopsis	–	0.4 ± 0.2
Yellow salsify	0.1 ± 0.0	0.0 ± 0.0
American vetch	0.3 ± 0.2	0.8 ± 0.2

Constancy

Average canopy cover values presented above provide an estimate of relative importance of each species within a stand or cover type. However, these values do not show how this species is distributed across the area. In order to understand how a fire influences the species, it is important to know how fire influences this distribution. Constancy values provide this information.

Constancy is a synthetic characteristic of a community, rather than a single stand. It is based on species encountered in releves, in this case microplots. Thus, constancy (as defined by Barbour et al. 1980) is the number of microplots within a plot that contain the species, expressed as a percentage (USDA Forest Service 1987). Average constancy values express how evenly the species is distributed throughout the plots and community.

Average constancy values are presented in Tables 16-21. Data were grouped by year-classes to provide an insight into changes over time following a fire. In some comparisons, sufficient data were available to provide for four year-classes (1-2, 3-5, 6-10, and > 10 years postfire). In other comparisons, year-classes were fewer or not feasible, depending on available data.

Inclusion of all recorded species in the tables was considered to be undesirable. Many of these species are represented by occasional individuals; such species provide insufficient data to show trends following a fire. For each of the well-represented cover types, those species present in significant amounts were selected for inclusion in the table for that type. These include species considered to be important as high successional species, forage species, weeds, and wildlife foods and cover.

Wheatgrass – Grama – Needlegrass Cover Type

Constancy values of individual plant species on unburned sites, sites 1-5 years postburn, and sites >5 years postburn are presented in Table 16. Two shrubs, 15 graminoids, and 10 forbs were present in significant amounts to provide information relative to fire effects on individual species.

Fringed sage was the most common shrub within this cover type. Constancy values for this shrub was somewhat lower than on unburned sites for the first 1-5 years postfire, then was greater after 5 years. Silver sage had a higher constancy value in all burn age classes than on unburned sites. Both species possess dormant underground buds, and appear to resprout and spread following a fire within this cover type.

Response of grasses and sedges to fire varied by species. Of the 15 species present in significant amounts, 5 had lower constancy values > 5 years post fire, 3 were about the same, and 7 species had greater values. Constancy values especially increased over this period for crested wheatgrass (*Agropyron cristatum*), prairie Junegrass, Sandberg bluegrass and green needlegrass. Constancy for bluebunch wheatgrass, buffalograss, prairie sandreed, and plains muhly declined to less than one-half of the values of unburned sites. Bluebunch wheatgrass, blue grama, and needle-and-thread grass were more widely distributed than all other species on burned and unburned plots.

Five forb species increased on burned sites during the > 5-year period, 2 species declined, and 3 remained about the same. Western yarrow, rosy pussytoes (*Antennaria rosea*), cudweed sagewort, and round-leafed thermopsis had greater than twice the distribution on burned sites > 5 years old compared to unburned sites. Scarlet globemallow (*Sphaeralcea* *coccinea*) increased in distribution during the first 5 years postburn, then declined considerably after the fifth year.

Wheatgrass Cover Type

Constancy values of individual plant species on unburned and burned sites are presented in Table 17. Three shrubs, 8 graminoids, and 5 forbs were present in significant amounts to provide information relative to fire effects on individual species.

Constancy values for Rocky Mountain juniper, skunkbush sumac and western snowberry were somewhat lower on burned sites. Burning reduced the distribution of these species, although all were still present.

Response of grasses and sedges to fire varied by species. Of the 8 species present in significant amounts, 3 had lower constancy values on burned areas, bluebunch wheatgrass had about the same distribution, and 4 species had greater values. Constancy values especially increased on burned sites for western wheatgrass.

Of the 5 forb species assessed, 2 increased, two declined, and one remained about the same in distribution following a fire.

Big Sagebrush – Grass Cover Type

Constancy values of individual plant species on unburned sites, sites 1-5 years postburn, and sites >5 years postburn are presented in Table 18. Two shrubs, 8 graminoids, and 10 forbs were present in significant amounts to provide information relative to fire effects on individual species.

Big sagebush was the most common shrub within this cover type. Constancy of this shrub was considerably lower on burned sites for the first 1-5 years postfire, and recovered slightly after 5 years. Fringed sage constancy was reduced by fire during the

Table 16. Constancy of significant plant species on unburned and burned sites for the Wheatgrass-Grama-Needlegrass cover type.

Species	Unburned Sites (n = 23)	Burned Sites 1-5 Years (n = 14)	Burned Sites > 5 Years (n = 9)
	Percent		
Shrubs			
Artemisia frigida	12.7	11.1	15.5
Artemisia cana	2.2	4.3	3.6
Grasses and Sedges			
Crested wheatgrass	0.9	2.3	8.4
Western wheatgrass	59.1	58.0	51.6
Bluebunch wheatgrass	6.4	10.0	1.3
Red threeawn	1.0	1.7	3.1
Sideoats grama	6.8	6.9	5.8
Blue grama	54.4	49.1	50.7
Japanese brome	11.7	3.7	15.1
Buffalograss	1.7	5.4	0
Calamovilfa longifolia	4.9	7.1	1.7
Threadleaf sedge	19.8	12.3	22.2
Prairie Junegrass	17.4	19.1	33.4
Plains muhly	3.1	1.7	0.4
Sandberg bluegrass	7.1	1.4	13.3
Needle-and-thread grass	57.8	45.4	46.7
Green needlegrass	8.5	4.6	12.5
Forbs			
Western yarrow	2.8	2.9	8.4
Rosy pussytoes	0.5	0.6	7.8
Cudweed sagewort	4.5	1.7	15.1
Scarlet beeblossom	10.3	10.6	8.4
Plains pricklypear	1.7	4.0	0.4
Hood's phlox	6.6	5.5	10.7
Scarlet globemallow	9.7	14.6	0.4
Dandelion	10.8	9.4	10.7
Round-leafed thermopsis	3.7	2.3	13.3
Yellow salsify	4.3	1.1	3.6

Table 17. Constancy of significant plant species on unburned and burned sites for the Wheatgrass cover type.

Species	Unburned Sites (n = 7)	Burned Sites (n = 7)
	Percent	
Trees and Shrubs		
Rocky Mountain juniper	5.7	1.7
Skunkbush sumac	4.0	1.1
Western snowberry	5.1	3.4
Grasses and Sedges		
Western wheatgrass	46.3	62.3
Bluebunch wheatgrass	22.9	23.4
Blue grama	2.9	4.0
Japanese brome	15.4	18.9
Threadleaf sedge	4.0	1.1
Prairie junegrass	6.9	4.6
Kentucky bluegrass	5.1	4.6
Sandberg bluegrass	0.6	2.9
Forbs		
Textile onion	4.0	4.6
Western yarrow	14.9	7.4
Dandelion	11.4	9.7
Yellow salsify	1.7	2.3
American vetch	3.4	10.3

first 5 years postfire, but had recovered to more than twice the constancy of unburned sites after 5 years.

Response of grasses and sedges to fire varied by species. Constancy for western wheatgrass increased within the first 5 years following a fire, then declined on sites > 5 years postfire. Blue grama, green needlegrass and needle-and-thread grass constancy values were lower during the first 5 years following a fire, then increased above those of unburned sites after 5 years.

Five forb species increased on burned sites during the > 5-year period, 4 species declined, and 1 remained about the same. Distributions of brittle pricklypear and plains pricklypear were reduced by fire > 5 years after a fire. Clubmoss constancy was considerably reduced 1-5 years after a fire, but had completely recovered on burned sites over 5 years of age.

Mixed Shrub – Grass Cover Type

Constancy estimates of individual plant species on unburned sites, sites 1-10 years postburn, and sites >10 years postburn are presented in Table 19. Seven shrubs, 9 graminoids, and 10 forbs were present in significant amounts to provide information relative to fire effects on individual species.

Western snowberry was the most common shrub within this cover type. Constancy of this shrub increased on burned sites for the first 10 years postfire, then declined below that of unburned sites on older burned sites. Silver sagebrush constancy was reduced by fire in all ages of burns, while Rocky Mountain juniper disappeared on burned sites. Chokecherry (*Prunus virginiana*) distribution was reduced during the first 10 years postfire, but increased to more than twice that of unburned sites after 10 years.

Response of grasses and sedges to fire varied by species. In general, constancy for western wheatgrass, prairie junegrass, green needlegrass and needle-and-thread grass was greater on burned sites where the wildfire had occurred > 10 years prior to our study. Constancy of bluebunch wheatgrass declined considerably on sites 1-10 years postfire, then recovered to that of unburned sites after 10 years. Smooth brome (*Bromus inermis*) and Kentucky bluegrass, two exotic sod-forming grasses, increased in constancy during the first 10 years postfire, then declined to about the same constancy on older burned sites.

Eight forb species increased on burned sites of all ages, 1 declined, and 1 remained about the same. It is possible that a hot fire produced by the woody fuel left sufficient bare ground to allow seed germination and plant establishment of most of these forb species.

Silver Sagebrush – Grass Cover Type

Constancy values of individual plant species on unburned and burned sites are presented in Table 20. Three shrubs, 13 graminoids, and 13 forbs were present in significant amounts to provide information relative to fire effects on individual species.

Constancy for silver sagebrush was slightly lower on burned sites, although the species continued to be present in one-fourth of the plots. The distribution of silver sagebrush was reduced to about one-third that of unburned sites, while that of western snowberry was slightly reduced by burning.

Response of grasses and sedges to fire varied by species. Of the 13 species present in significant amounts, 3 had lower constancy values on burned areas, 5 had about the same distribution, and 5 species had greater values. Constancy values were somewhat reduced by burning for western wheatgrass, and needle-and-thread grass. Blue grama, green needlegrass, and Sandberg bluegrass increased in distribution on burned sites.

Of the 13 forb species assessed, 5 increased, 6 declined, and 2 remained about the same in distribution following a fire.

Juniper – Grass Cover Type

Constancy values of individual plant species on unburned and burned sites are presented in Table 21. Three shrubs, 5 graminoids, and 8 forbs were present in significant amounts to provide information relative to fire effects on individual species.

Constancy for the three shrub species declined following a fire. Rocky Mountain juniper was greatly reduced by fire, while that of skunkbush sumac and western snowberry was about one-third that of unburned sites.

Response of grasses and sedges to fire varied by species. Western wheatgrass and green needlegrass increased in constancy following a fire, while bluebunch wheatgrass declined in distribution.

Of the 8 forb species assessed, 4 increased, 1 declined, and 3 remained about the same in distribution following a fire.

Table 18. Constancy of significant plant species on unburned and burned sites for the Big Sagebrush-Grass cover type.

Species	Unburned Sites (n = 23)	Burned Sites 1-5 Years (n = 14)	Burned Sites > 5 Years (n = 9)
	Percent		
Shrubs			
Fringed sage	5.2	2.9	13.3
Big sagebrush	50.8	7.7	11.1
Grasses and Sedges			
Western wheatgrass	74.4	82.6	60.4
Bluebunch wheatgrass	10.3	8.0	7.6
Blue grama	30.6	19.2	42.2
Japanese brome	14.8	18.3	11.1
Prairie Junegrass	33.2	26.6	19.1
Sandberg bluegrass	37.2	38.0	37.3
Needle-and-thread grass	9.2	5.2	24.4
Green needlegrass	7.8	5.4	9.3
Forbs			
Western yarrow	9.2	8.9	4.4
Rosy pussytoes	0.9	0.9	1.0
Yellow sweetclover	12.8	11.1	18.2
Brittle pricklypear	2.1	1.7	0.4
Plains pricklypear	7.1	2.6	4.0
Selaginella densa	20.0	4.6	23.1
Scarlet globemallow	1.9	6.0	9.8
Dandelion	9.4	10.0	23.3
Yellow salsify	1.4	1.4	5.3
American vetch	17.7	26.6	12.9

Table 19. Constancy of significant plant species on unburned and burned sites for the Mixed Shrub-Grass cover type.

Species	Unburned Sites (n = 18)	Burned Sites 1-10 Years (n = 8)	Burned Sites ≥ 10 Years (n = 8)
		Percent	
Trees and Shrubs			
Silver sagebrush	5.5	2.5	1.0
Creeping juniper	5.8	_	6.5
Rocky Mountain juniper	22.0	_	_
Chokecherry	9.3	1.5	24.0
Skunkbush sumac	3.5	2.5	3.5
Rose	20.3	28.0	23.0
Western snowberry	58.7	68.5	46.0
Grasses and Sedges			
Western wheatgrass	7.0	27.5	17.0
Bluebunch wheatgrass	18.3	1.0	18.0
Smooth brome	14.3	19.0	12.5
Japanese brome	18.3	25.5	15.0
Prairie junegrass	5.3	3.5	13.5
Kentucky bluegrass	13.5	23.5	12.0
Sandberg bluegrass	2.0	1.0	1.5
Needle-and-thread grass	1.8	1.0	7.5
Green needlegrass	3.8	9.5	7.0
Forbs			
Western yarrow	12.5	27.0	24.5
Rosy pussytoes	3.5	1.0	1.0
Cudweed sagewort	4.3	18.0	11.5
Canada thistle	2.3	_	7.0
Blue lettuce	0.8	4.5	11.5
Prickly lettuce	6.0	13.5	8.5
Goldenrod	1.8	3.5	11.0
Dandelion	11.5	21.0	17.5
Yellow salsify	1.0	3.0	1.0
American vetch	2.8	4.5	8.0

Table 20. Constancy of significant plant species on unburned and burned sites for the Silver Sagebrush-Grass cover type.

Species	Unburned Sites (n = 11)	Burned Sites (n = 11)
	Percent	
Shrubs		
Silver sagebrush	28.7	26.2
Fringed sage	9.1	2.9
Western snowberry	2.2	1.5
Grasses and Sedges		
Western wheatgrass	41.1	34.2
Bluebunch wheatgrass	5.8	4.7
Red threeawn	6.9	10.9
Blue grama	35.6	43.3
Smooth brome	9.1	9.1
Japanese brome	35.6	40.4
Prairie sandreed	10.9	9.5
Prairie Junegrass	28.4	20.4
Kentucky bluegrass	4.4	5.8
Sandberg bluegrass	6.5	16.0
Little bluestem	7.3	6.2
Needle-and-thread grass	36.4	31.6
Green needlegrass	5.8	14.5
Forbs		
Western yarrow	3.6	3.3
Spotted knapweed	7.6	4.7
Blanket-flower	1.1	4.4
Scarlet beeblossom	4.0	2.2
Brittle pricklypear	4.0	2.5
Plains pricklypear	4.0	2.5
Hood's phlox	5.1	2.2
Clubmoss	8.4	3.6
Scarlet globemallow	12.4	16.7
Dandelion	10.2	16.4
Round-leafed thermopsis	5.5	9.5
Yellow salsify	6.9	7.3
American vetch	0.7	3.6

Table 21. Constancy of significant plant species on unburned and burned sites for the Juniper-Grass cover type.

Species	Unburned Sites (n = 6)	Burned Sites (n = 6)
	Percent	
Trees and Shrubs		
Rocky Mountain juniper	31.1	1.3
Skunkbush sumac	3.3	0.7
Western snowberry	11.3	4.0
Grasses and Sedges		
Western wheatgrass	20.0	30.7
Bluebunch wheatgrass	52.0	36.0
Japonese brome	14.0	39.3
Prairie Junegrass	6.7	5.3
Green needlegrass	4.7	14.0
Forbs		
Western yarrow	6.7	17.3
Rosy pussytoes	2.0	1.3
Yellow sweetclover	8.0	31.3
Brittle pricklypear	2.7	0.7
Dandelion	8.0	19.3
Round-leafed thermopsis	5.0	5.0
Yellow salsify	2.7	2.7
American vetch	18.0	29.3

EFFECTS OF FIRE ON VEGETATION

Vegetation Similarity Values for Unburned Versus Burned Sites

Vegetation similarity values (100 equals total similarity) are compared between unburned cover types and paired burned sites of various ages. These measures of similarity allow one to determine how similar the vegetation is following a fire on individual cover types, rangelands in general, and grasslands in general. These values provide answers to the following questions:

1) Is there a complete change in the vegetation following a wildfire?
2) Is there no change in the vegetation following a wildfire?
3) If there is a partial change in the vegetation following a wildfire, how similar is the vegetation of a burned area to that of an unburned area?
4) Assuming the vegetation is not totally similar on unburned and burned sites, does the vegetation of burned sites become more similar to that of unburned sites over time?

Combined Grassland and Shrubland Cover Types

Similarity values are shown in Table 22. Sufficient plot data were available to allow comparisons between unburned plots and burned plots 1-2 years, 3-5 years, 6-10 years, and > 10 years of age. Values ranged from 58.3 to 64.0. These values changed only slightly throughout different ages of burns. Apparently, plant succession is not returning the burned vegetation to that of unburned sites to any degree.

Combined Grassland Cover Types

Similarity values are shown in Table 22. Sufficient plot data were available to allow comparisons between unburned plots and burned plots 1-2 years, 3-5 years, 6-10 years, and > 10 years of age. Values ranged from 62.6 to 65.6. These values changed only slightly throughout different ages of burns.

Wheatgrass-Grama-Needlegrass and Big Sagebrush-Grass Cover Types

Similarity values are shown in Table 23. Data for burned plots are grouped into 1-5 years and > 5 years age groups. Similarity values when comparing burned sites 1-5 years of age to unburned plots are essentially equal for both vegetation types (65.6 and 65.7). These values changed only slightly (64.4 and 67.2) on burned sites > 5 years old.

Mixed Shrub – Grass Cover Type

Similarity values are shown in Table 24. Data for burned plots are grouped into 1-10 years and > 10 years age groups. Similarity values of burned sites show considerable dissimilarity between burned and unburned sites. Slightly over one-half of the vegetation on burned sites is similar to that present before the fires occurred. These values changed only slightly from 1-10 years postburn (54.5) to > 10 years postburn (56.0).

Wheatgrass, Silver Sagebrush – Grass, Juniper – Grass, and Conifer Cover Types

Table 25 presents vegetation similarity values (0-100) between all burned and unburned sites for each vegetation type. Insufficient plot data were available to group burned sites by age classes. Similarity values were highest for the Silver Sagebrush – Grass vegetation type (65.4) and ranged downward to a low of 40.9 in the Juniper – Grass vegetation type.

Table 22. Vegetation similarity values for combined grassland range types and combined grassland and shrubland cover types on unburned and burned plots.

Ages after burned	1-2 years		3-5 years		6-10 years		> 10 years	
	Unburned vs. Burned		Unburned vs.Burned		Unburned vs.Burned		Unburned vs.Burned	
	(n)	μ ± SE	(n)	μ ± SE	(n)	μ ± SE	(n)	μ ± SE
Combined grassland and shrubland range types	15	59.5 ± 3.5	29	64.0 ± 3.4	23	58.3 ± 3.0	30	63.2 ± 2.3
Combined Grassland range types	7	65.6 ± 2.3	10	63.3 ± 3.5	9	62.6 ± 3.6	12	64.7 ± 4.4

Table 23. Vegetation similarity values for Wheatgrass-Grama-Needlegrass and Big Big Sagebrush-Grass cover types on unburned and burned plots.

Ages after burned	1-5 years		> 5 years	
	Unburned vs. Burned		Unburned vs.Burned	
	(n)	μ ± SE	(n)	μ ± SE
Wheatgrass-Grama Needlegrass	14	65.6 ± 2.2	9	64.4 ± 4.2
Big Sagebrush-Grass	14	65.7 ± 5.3	9	67.2 ± 2.9

Table 24. Vegetation similarity values for Mixed Shrub-Grass cover type on unburned and burned plots.

Ages after burned	1-10 years		> 10 years	
	Unburned vs. Burned		Unburned vs.Burned	
	(n)	μ ± SE	(n)	μ ± SE
Mixed Shrub - Grass	8	54.5 ± 8.0	8	56.0 ± 3.8

Table 25. Vegetation similarity values for Wheatgrass, Silver Sagebrush-Grass, Juniper-Grass and Conifer cover types on unburned and burned plots.

Ages after burned	All Years	
	Unburned vs. Burned	
	(n)	µ ± SE
Wheatgrass	7	56.2 ± 4.9
Silver Sagebrush-Grass	11	65.4 ± 2.9
Juniper-Grass	6	40.9 ± 6.4
Conifer	11	55.2 ± 3.3

Effect of Wildfires on Vegetation Similarity

In viewing similarity values among all of the vegetation types and groups of types, it is obvious that wildfires do effect an immediate change in the vegetation on a site. Once the plant community is altered by fire, little change toward greater similarity occurs, regardless of the age of the burned site. Resistance of a community to return to that present before it burned might be the result of a multiplicity of factors.

Some of the burned sites were not in a natural or potential condition before the fire occurred. Since fire is considered a natural phenomenon on these rangelands, burned sites possibly support more-natural vegetation; thus, plant succession would not move the burned vegetation closer to a pre-burn condition.

Some of the woody species have increased or invaded into communities where fires were absent for extended times. These species, especially *Artemisia tridentata, Juniperus scopulorum*, and *Juniperus horizontalis,* were significantly reduced by fire. Herbaceous species quickly take their place, providing sufficient competition to restrict survival of seedlings of these woody species.

Community Diversity

Diversity indices are used by ecologists to provide quantitative expressions with which the diversity of 1 community (or data set) can be compared to that of another (Hunter 1990). Usually a data set is a community and the elements of a set are plant species. In our study, diversity is calculated as an average across all macroplots (unburned, burned age groups). Thus, changes in community diversity can be compared between or among unburned and burned, or unburned and burned by age groups).

Ecologists calculate diversity by use of formulas that combine species richness (number of species present) and evenness (distribution of abundance among different species) to determine whether a community with more richness or one with more evenness has greater diversity. These formulas are weighted more heavily to species richness (Hunter 1990). Single species communities are defined as having a diversity of zero.

Combined Grassland and Shrubland Cover Types

All grassland and shrubland vegetation types were combined to assess community diversity characteristics on rangelands in general. These values are presented in Table 26.

Average Shannon-Wiener (S-W) diversity index values for these vegetation types were 1.8 on burned plots 1-2 years old and 1.7 on paired unburned plots. S-W indices remained slightly higher on burned plots than paired unburned plots through 3-5 years, 6-10 years, and after 10 years. The oldest burned plots had S-W index values of 2.1 compared to values of 1.9 on paired unburned plots. High S-W indices (greater than 1.0) are computed when the plot has high coverages and many species. The high S-W index values across the grassland and shrubland cover types reflect relatively high species diversity. Any increase in S-W values following a fire is based on an increase in species evenness.

Table 26 Community diversity characteristics for combined grassland and shrubland cover types on unburned and burned plots.

Ages after burned	1-2 years (n = 15)		3-5 years (n = 29)		6-10 years (n = 23)		> 10 years (n = 30)	
	Unburned vs.	Burned	Unburned vs.	Burned	Unburned vs.	Burned	Unburned vs.	Burned
	μ ± SE	μ ± SE	μ ± SE	μ ± SE	μ ± SE	μ ± SE	μ ± SE	μ ± SE
S-W index	1.7 ± 0.1	1.8 ± 0.1	1.9 ± 0.1	2.0 ± 0.1	1.9 ± 0.1	1.9 ± 0.1	1.9 ± 0.1	2.1 ± 0.1
Nnumber of spp.	4.2 ± 0.2	4.1 ± 0.2	4.6 ± 0.2	4.7 ± 0.3	4.1 ± 0.3	4.4 ± 0.3	4.8 ± 0.3	5.1 ± 0.3
Species richness	14.9 ± 1.5	16.3 ± 1.6	18.8 ± 1.4	19.4 ± 1.4	16.1 ± 1.5	18.8 ± 1.3	8.8 ± 1.5	21.4 ± 1.6
Dominance index	29.0 ± 3.6	26.1 ± 3.7	25.0 ± 2.9	22.0 ± 2.4	25.4 ± 3.5	24.1 ± 3.5	28.0 ± 3.2	20.9 ± 2.7

The average number of species encountered in microplots across a macroplot remained relatively equal in paired unburned and burned plots in all comparisons. In burned plots > 10 years of age, S-W index values were 5.1, while paired unburned plots had a value of 4.8. Any real increase would indicate an increased recruitment of new species within the macroplot.

Species richness (total species encountered in all microplots) also indicates a recruitment of new species within the macroplot. Average number of species encountered within a macroplot was 16.3 on burned plots 1-2 years old, and 14.9 on paired unburned plots. Average number of species remained slightly higher on burned plots than paired unburned plots through 3-5 years, 6-10 years, and after 10 years. Those burned macroplots > 10 years of age had an average of 21.4 species, compared to 18.8 species on paired unburned plots.

The average dominance index for a plot is calculated as a number from 0 to 100 and indicates the degree of dominance by 1 or more species on a plot. Plots with high coverages of 1 species and low coverages of remaining species tend to generate high dominance indices (near 100). Thus, a decrease in average dominance index indicates a decrease in dominance over time. Average dominance indices were somewhat lower on burned macroplots than paired unburned macroplots in all comparisons. Index values were 26.1 on burned plots 1-2 years old, and 29.0 on paired unburned plots. Average dominance index values remained slightly lower on burned plots than paired unburned plots through 3-5 years, 6-10 years, and after 10 years. Those burned macroplots > 10 years of age had an average index of 20.9, compared to an index of 28.0 on paired unburned plots.

Grassland and shrubland cover types throughout the Northern Mixed Prairie generally have somewhat greater species diversity and species numbers following a wildfire. This is contrasted with the decrease in dominance by one or a few species on the burned areas.

Combined Grassland Cover Types

All grassland vegetation types were combined to assess community diversity characteristics on grasslands in general. These values are presented in Table 27.

Average Shannon-Wiener (S-W) diversity index values for grasslands were 1.6 on burned plots 1-2 years old and 1.7 on paired unburned plots. S-W indices remained essentially the same on burned and paired unburned plots through 3-5 years, 6-10 years, and after 10 years. The oldest burned plots (> 10 years) had S-W index values of 2.2 compared to values of 2.1 on paired unburned plots. High S-W indices (greater than 1.0) are computed when the plot has high coverages and many species. The high S-W index values across the grassland vegetation types reflect relatively high species diversity.

The average number of species encountered in microplots across a macroplot remained relatively equal in paired unburned and burned plots in all comparisons. In burned plots > 10 years of age, S-W index values were 5.2, while paired unburned plots had a value of 5.4.

Table 27 Community diversity characteristics for combined grassland cover types on unburned and burned plots.

Ages after burned	1-2 years (n = 7)		3-5 years (n = 10)		6-10 years (n = 9)		> 10 years (n = 12)	
	Unburned	vs.Burned	Unburned	vs.Burned	Unburned	vs.Burned	Unburned	vs.Burned
	μ ± SE	μ ± SE	μ ± SE	μ ± SE	μ ± SE	μ ± SE	μ ± SE	μ ± SE
S-W index	1.6 ± 0.2	1.7 ± 0.2	2.0 ± 0.2	2.0 ± 0.2	2.1 ± 0.2	2.0 ± 0.2	2.1 ± 0.2	2.2 ± 0.2
Nnumber of spp.	3.9 ± 0.3	3.9 ± 0.4	4.6 ± 0.3	4.4 ± 0.3	4.6 ± 0.7	4.8 ± 0.7	5.4 ± 0.6	5.2 ± 0.6
Species richness	13.1 ± 1.4	13.7 ± 2.0	19.9 ± 1.3	18.7 ± 2.0	19.0 ± 2.3	20.8 ± 2.8	19.8 ± 2.5	22.4 ± 2.5
Dominance index	30.0 ± 5.5	31.4 ± 6.3	23.8 ± 6.6	22.9 ± 4.4	19.2 ± 3.1	24.5 ± 6.8	19.8 ± 4.0	21.3 ± 5.0

Species richness (total species encountered in all microplots) also indicates a decrease or recruitment of new species within the macroplot. Average number of species encountered within a macroplot was 13.7 on burned plots 1-2 years old, and 13.1 on paired unburned plots. Average number of species remained about the same on burned plots than paired unburned plots through 3-5 years and 6-10 years. Those burned macroplots > 10 years of age had an average of 22.4 species, compared to 19.8 species on paired unburned plots.

Average dominance indices were generally higher on burned macroplots than paired unburned macroplots, except in burns 3-5 years of age. Index values were 31.4 on burned plots 1-2 years old, and 30.0 on paired unburned plots. Average dominance index values were slightly lower on burned plots 3-5 years of age than paired unburned plots. Values on burned macroplots then rose above those of unburned paired plots 6-10 years and > 10 years of age. Those burned macroplots > 10 years of age had an average index of 21.3, compared to an index of 19.8 on paired unburned plots.

Community diversity of grasslands throughout the Northern Mixed Prairie did not vary much following a wildfire. Diversity characteristics of burned and unburned grasslands remained similar even on burned areas > 10 years of age.

Wheatgrass-Grama-Needlegrass Cover Type

Community diversity characteristics are presented in Table 28. Average Shannon-Wiener diversity index values were 1.8 on burned plots 1-5 years old and on paired unburned plots. S-W indices increased slightly to 1.9 on burned sites > 5 years old and were 2.1 on paired unburned plots. High S-W indices (greater than 1.0) are computed when the plot has high coverages and many species. The high S-W index values across the Wheatgrass-Grama-Needlegrass Cover Type reflect relatively high species diversity.

The average number of species encountered in microplots across a macroplot remained relatively equal in paired unburned and burned plots in all comparisons. In burned plots > 5 years of age and paired unburned plots, S-W index values were the same at 5.8.

Table 28. Community diversity characteristics for Wheatgrass-Grama-Needlegrass cover type on unburned and burned plots.

Ages after burned	1-5 years (n = 14)		> 5 years (n = 9)	
	Unburned vs. Burned		Unburned vs.Burned	
	μ ± SE	μ ± SE	μ ± SE	μ ± SE
Avg. S-W index	1.8 ± 0.2	1.8 ± 0.1	2.1 ± 0.2	1.9 ± 0.2
Avg. number of species	4.3 ± 0.3	4.2 ± 0.3	5.8 ± 0.5	5.8 ± 0.7
Species richness	16.3 ± 1.2	15.5 ± 1.6	18.7 ± 2.4	21.6 ± 2.7
Avg. dominance index	27.9 ± 5.3	29.0 ± 4.1	21.7 ± 4.4	29.6 ± 7.4

Species richness within a macroplot was 15.5 on burned plots 1-5 years old, and 16.3 on paired unburned plots. Species richness increased in burned macroplots > 5 years old and paired unburned plots to 21.6 and 18.7, respectively. This increase in species richness indicates recruitment of new species on older burned sites beyond those present on burns 1-5 years old and unburned sites.

Average dominance indices were higher on burned macroplots than paired unburned macroplots. Index values were 29.0 on burned plots 1-5 years old, and 27.9 on paired unburned plots. Average dominance index values increased slightly to 29.6 on burned plots > 5 years after a fire, while those on unburned paired plots were 21.7.

Community diversity of the Wheatgrass-Grama-Needlegrass Cover Type throughout the Northern Mixed Prairie varied somewhat from that of paired unburned sites following a wildfire. On burned areas > 5 years old, the S-W index Diversity index was slightly lower, average number of species within a microplot was the same, and species richness within a macroplot was somewhat higher. The higher average dominance index indicates a relatively higher dominance by one or a few species on burned areas compared to unburned adjacent sites.

Big Sagebrush-Grass Cover Type

Community diversity characteristics are presented in Table 29. Average Shannon-Wiener diversity index values were 2.0 on burned plots 1-5 years old and 1.8 on paired unburned plots. S-W indices declined slightly to 1.9 on burned sites > 5 years old and 1.6 on paired unburned plots. High S-W indices (greater than 1.0) are computed when the plot has high coverages and many species. The high S-W index values across the Big Sagebrush-Grass Cover Type reflect relatively high species diversity.

The average number of species encountered in microplots across a macroplot remained relatively equal in paired unburned and burned plots in all comparisons. In burned plots > 5 years of age and paired unburned plots, S-W index values were 4.3 and 4.4, respectively.

Species richness within a macroplot was 16.7 on burned plots 1-5 years old, and 15.6 on paired unburned plots. Species richness decreased in burned macroplots > 5 years old and paired unburned plots to 14.8 and 13.4, respectively. This decrease in species richness indicates a loss of species on older burned sites beyond those present on burns 1-5 years old.

Average dominance indices were lower on burned macroplots than paired unburned macroplots. Index values were 19.8 on burned plots 1-5 years old, and 25.9 on paired unburned plots. Average dominance index values increased slightly to 20.9 on burned plots > 5 years after a fire, while those on unburned paired plots were higher at 29.0.

Table 29. Community diversity characteristics for Big Sagebrush – Grass cover type on unburned and burned plots.

Ages after burned	1-5 years (n = 14)		> 5 years (n = 9)	
	Unburned vs.	Burned	Unburned vs.	Burned
	μ ± SE	μ ± SE	μ ± SE	μ ± SE
Avg. S-W index	1.8 ± 0.1	2.0 ± 0.1	1.6 ± 0.1	1.9 ± 0.1
Avg. number of species	4.6 ± 0.3	4.2 ± 0.3	4.4 ± 0.2	4.3 ± 0.3
Species richness	15.6 ± 2.2	16.7 ± 1.8	13.4 ± 2.1	14.8 ± 1.3
Avg. dominance index	25.9 ± 3.2	19.8 ± 2.5	29.0 ± 2.8	20.9 ± 1.3

Community diversity of the Big Sagebrush-Grass Cover Type throughout the Northern Mixed Prairie varied somewhat from that of paired unburned sites following a wildfire. On burned areas of various ages, the S-W index Diversity index was somewhat higher, average number of species within a microplot was somewhat lower, and species richness within a macroplot was somewhat higher. The higher average dominance index on unburned sites indicates a relatively higher dominance by one or a few species. This dominance was mostly expressed by big sagebrush. Since big sagebrush plants do not sprout following a fire, this dominant shrub was significantly reduced on burned sites.

Mixed Shrub-Grass Cover Type

Community diversity characteristics are presented in Table 30. Average Shannon-Wiener diversity index values were 1.8 on burned plots 1-10 years old and 1.5 on paired unburned plots. S-W indices increased to 2.2 on burned sites > 10 years old but remained steady at 1.5 on paired unburned plots. High S-W indices (greater than 1.0) are computed when the plot has high coverages and many species. The high S-W index values across the Mixed Shrub-Grass Cover Type reflect relatively high species diversity.

Table 30. Community diversity characteristics for Mixed Shrub-Grass cover type on unburned and burned plots.

Ages after burned	1-10 years (n = 8)		> 10 years (n = 8)	
	Unburned vs.	Burned	Unburned vs.	Burned
	μ ± SE	μ ± SE	μ ± SE	μ ± SE
Avg. S-W index	1.5 ± 0.2	1.8 ± 0.2	1.5 ± 0.3	2.2 ± 0.2
Avg. number of species	4.3 ± 0.4	5.0 ± 0.5	4.3 ± 0.6	5.6 ± 0.7
Species richness	16.6 ± 2.7	22.0 ± 3.3	20.1 ± 3.3	24.3 ± 3.3
Avg. dominance index	38.5 ± 6.6	33.3 ± 7.6	42.7 ± 7.7	20.8 ± 5.6

The average number of species encountered in microplots across a macroplot was higher on burned plots than on paired unburned plots in all comparisons. The number remained at 4.3 on unburned plots, but increased to 5.0 on burns 1-10 years old and to 5.6 on burns older that 10 years.

Species richness within a macroplot was 22.0 on burned plots 1-10 years old, and 16.6 on paired unburned plots. Species richness increased in burned macroplots > 10 years old and in paired unburned plots to 24.3 and 20.1, respectively. This increase in species richness indicates a recruitment of species on burned sites of all ages.

Average dominance indices were lower on burned macroplots than paired unburned macroplots. Index values were 33.3 on burned plots 1-19 years old, and 38.5 on paired unburned plots. Average dominance index values declined to 20.8 on burned plots > 10 years after a fire, while those on unburned paired plots were considerably higher at 42.7.

Community diversity of the Mixed Shrub-Grass Cover Type throughout the Northern Mixed Prairie is higher on burned sites of all ages than on unburned sites. Shrub species, which dominate this type, have the ability to sprout following a wildfire; however, the site is opened to recruitment of herbaceous species and spread of existing species. Thus, there is an increase in species on burned sites, and a decline in dominance of one or a few shrub species.

Wheatgrass Cover Type

Community diversity characteristics are presented in Table 31. Community diversity of the Wheatgrass Cover Type throughout the Northern Mixed Prairie were affected little by a wildfire. Average Shannon-Wiener diversity index values were 2.0 on burned and paired unburned plots. Average number of species in a microplot was 3.4 in unburned sites and 3.3 in burned sites. Species richness in a macroplot was 17.3 in unburned sites and 18.0 in burned sites. Average dominance index was 19.7 in unburned sites and slightly lower at 18.6 in burned sites.

Silver Sagebrush-Grass Cover Type

Community diversity characteristics are presented in Table 32. Community diversity of the Silver Sagebrush-Grass Cover Type throughout the Northern Mixed Prairie were affected little by a wildfire. Average Shannon-Wiener diversity index values were 2.1 on burned and paired unburned plots. Average number of species in a microplot was 5.0 in unburned sites and 5.1 in burned sites. Species richness in a macroplot was 20.7 in unburned sites and 20.1 in burned sites. Average dominance index was 18.5 in unburned sites and slightly higher at 19.7 in burned sites.

Juniper-Grass Cover Type

Community diversity characteristics are presented in Table 33. Community diversity of the Juniper-Grass Cover Type throughout the Northern Mixed Prairie was significantly affected by a wildfire. Average Shannon-Wiener diversity index values were 2.2 on burned plots and 1.6 on paired unburned plots. Average number of species in a microplot was 2.8 in unburned sites and 4.3 in burned sites. Species richness in a macroplot was 14.5 in unburned sites and 22.0 in burned sites. Average dominance index was considerably reduced by burning; values for unburned sites (33.6) were almost twice that of unburned sites (17.6).

Juniper was a dominant species in unburned sites. Much or all of the juniper was killed by fire, greatly reducing dominance by this species and releasing nutrients, water and space for recruitment of new species.

Conifer Cover Types

Community diversity characteristics are presented in Table 34. Community diversity of the Conifer Cover Types was significantly affected by a wildfire. Average Shannon-Wiener diversity index values were 2.5 on burned plots and 2.2 on paired unburned plots. Average number of species in a microplot was 4.2 in unburned sites and 4.8 in burned sites. Species richness in a macroplot was 21.9 in unburned sites and 24.4 in burned sites. Burning reduced average dominance index; values were18.0 on unburned sites and reduced to 12.9 on burned sites.

Coniferous tree species exerted some dominance on unburned sites, although not to the degree exerted by juniper. Much or all of the trees were killed by fire; however, understory species, which increased on the burned sites, did not exhibit the dominance found on unburned sites.

Table 31. Community diversity characteristics for Wheatgrass cover type on unburned and burned plots.

Ages after burned	All Years (n = 7)	
	Unburned	Unburned
	µ ± SE	µ ± SE
Avg. S-W index	2.0 ± 0.1	2.0 ± 0.2
Avg. number of species	3.4 ± 0.5	3.3 ± 0.3
Species richness	17.3 ± 2..5	18.0 ± 2.5
Avg. dominance index	19.7 ± 2.7	18.6 ± 2.7

Table 32. Community diversity characteristics for Silver sagebrush – Grass cover type on unburned and burned plots.

Ages after burned	All Years (n = 11)	
	Unburned	Unburned
	μ ± SE	μ ± SE
Avg. S-W index	2.1 ± 0.1	2.1 ± 0.2
Avg. number of species	5.0 ± 0.5	5.1 ± 0.5
Species richness	20.7 ± 2.6	20.1 ± 2.3
Avg. dominance index	18.5 ± 3.0	19.7 ± 3.4

Table 33. Community diversity characteristics for Juniper – Grass cover type on unburned and burned plots.

Ages after burned	All Years (n = 6)	
	Unburned	Unburned
	μ ± SE	μ ± SE
Avg. S-W index	1.6 ± 0.2	2.2 ± 0.2
Avg. number of species	2.8 ± 0.4	4.3 ± 0.4
Species richness	14.5 ± 2.7	22.0 ± 2.4
Avg. dominance index	33.6 ± 6.9	17.6 ± 4.2

Table 34. Community diversity characteristics for Conifer cover types on unburned and burned plots.

Ages after burned	All Years (n = 11)	
	Unburned	Unburned
	μ ± SE	μ ± SE
Avg. S-W index	2.2 ± 0.1	2.5 ± 0.1
Avg. number of species	4.2 ± 0.6	4.8 ± 0.6
Species richness	21.9 ± 2.7	24.4 ± 2.5
Avg. dominance index	18.0 ± 3.4	12.9 ± 2.5

EFFECT OF FIRE ON VEGETATION STRUCURE

Vegetation structure on rangelands is an important attribute as it affects wildlife, livestock and biological processes. Determination of the vegetation structure on paired unburned and burned macroplots provides important information relative to potential structural changes following a fire. Villnow (1995) developed a structure classification system at three scales (micro, meso and macro) for Columbia River Basin rangelands. We modified Villnow's micro-scale classification system to produce a dicotomous key (Figure 7). This scale provides the greatest detail. Brown et al. (2000) suggested that the more detailed classifications are useful to ecologists and fire specialists attempting to describe and understand the more intricate aspects of fire. Villnow (1995) also developed state-and-transition models of disturbance as it influences vegetation structure for each vegetation type. Our study of fire as it influences structure will provide a means to fine-tune these models. Vegetation structure classification for unburned and paired burned macroplots are presented in Tables 35-42.

Wheatgrass-Grama-Needlegrass Cover Type

This cover type has a Closed Herbland structure when at or near climax in the Northern Mixed Prairie. Excessive grazing leads to an Open Herbland structure. Scattered shrubs (mostly *Artemisia* spp.) are occasionally present, especially when fire has been absent for an extended time. Twenty-three unburned/burned paired plots occurred within this vegetation type (Table 35).

Six of the unburned sites were a Closed Herbland structure. Five of the paired burned plots (1-12 years post-fire) remained a Closed Herbland, while one burned site (20 years post-fire) had changed to a Closed Herbland/Scattered Shrub Phase.

Fourteen of the unburned sites were an Open Herbland structure. All but 3 of the paired burned sites remained Open Herbland up to 9 years post-fire. Of the 3 burned plots that changed from Open Herbland, one was a Closed Herbland, one a Closed Mixed Herbland, and one an Open Herbland/Scattered Shrub Phase 2, 5 and four years post-fire.

Two of the unburned sites were a Closed Herbland/Scattered Shrub Phase structure. One of these was the same structure 5 years post-fire, while the other was a Closed Herbland 12 years post-fire.

One of the unburned sites was an Open Herbland/Scattered Shrub Phase. Shrubs were not present on the paired burned plot, resulting in an Open Herbland structure 9 years post-fire.

Wheatgrass Cover Type

This cover type has a Closed Herbland structure when at or near climax in the Northern Mixed Prairie. Excessive grazing leads to an Open Herbland structure. Scattered shrubs (mostly *Artemisia* spp.) are occasionally present, especially when fire has been absent for an extended time. Seven unburned/burned paired plots occurred within this vegetation type (Table 36).

Three of the unburned sites were an Open Herbland structure. The paired burned plots (1-17 years post-fire) remained an Open Herbland.

Three of the unburned sites were an Open Herbland/Scattered Shrub Phase structure. The paired burned plots (3-11 years post-fire) had changed to an Open Herbland structure. Wildfires had removed the big sagebrush from the sites.

One of the unburned sites was a Closed Herbland/ Scattered Shrub Phase structure. The paired site that had burned 11 years prior to our study was also a Closed Herbland/Scattered Shrub Phase structure. The reason why the big sagebrush was present on the site cannot be determined by our study. The flames of the fire may have missed some of the individual shrubs, or they may have been established from seeds after the burn but before the herbaceous cover fully recovered.

Big Sagebrush-Grass Cover Type

This cover type has a significant big sagebrush component. Various combinations of big sagebrush and other shrub species with an understory of grasses and forbs produced 7 different vegetation structures within 23 unburned/burned paired plots that occurred within this vegetation type (Table 37).

Twelve of the unburned sites were an Open Herbland/Scattered Shrub Phase structure. Ten paired burned plots (1-9 years post-fire) were changed to an Open Herbland structure. The big sagebrush had been killed by the fire and had not returned to these sites. Two paired burned plots (5-8 years post-fire) did not undergo a change in structure.

Four of the unburned sites were an Open Low Shrub/Mixed Herbaceous structure. The shrub component had been reduced on the paired burned sites, leading to an Open Herbland/Scattered Shrub Phase on 2 sites (4 years and 17 years post-fire). One burned site had a Closed Herbland structure 10 years post-fire, and the other was an Open Herbland structure 14 years post-fire.

Three of the unburned sites were a Mixed Shrub/Mixed Herbaceous structure. The shrub component had also been reduced by fire on burned plots, leading to an Open Herbland structure (4 years post-fire) on one site, and an Open Herbland/Scattered Shrub Phase structure (10 and 12 years post-fire) on two sites.

Four other unburned/burned plot comparisons were made within this cover type. One unburned site had a Closed Mixed Herbland/Scattered Shrub Phase structure that remained unchanged after 5 years post-burn. Another unburned site had a Closed Herbland/Scattered Shrub Phase structure that had an Open Herbland structure 16 years post-burn. A third unburned site had an Open Herbland structure, while the burned site had changed to Open Herbland/Scattered Shrub Phase 4 years post-burn. The fourth unburned site was classified as an Open Mid Shrub structure that changed to Open Herbland structure by 12 years post-burn.

Fescue Grassland Cover Type

This cover type was represented on 4 unburned/burned sites (Table 38). One unburned site with an Open Herbland/Scattered Shrub structure had changed to an Open Herbland structure 5 years post-burn. The remaining 3 unburned sites had an Open Herbland structure; of these, 2 did not undergo a change in structure after 13 and 18 years post-burn, while 1 changed to an Open Herbland/Scattered Shrub Phase structure 18 years post-burn.

Mixed Shrub-Grass Cover Type

Vegetation structure varied considerable within this cover type as the mix of shrubs and grasses of various heights and densities varied. Because of the natural variations of vegetation within this type, it is not possible to assign one structure as representative of this cover type. The cover type was represented on 16 unburned/burned sites (Table 39). Of these, the structure class had changed on 10 of the burned sites at the time of our assessment. From our review of the data, it appears that burning within this cover type caused few changes in the herbaceous component, while significant changes occurred within the shrub component on these 10 sites. Several shrub species may be present on a particular site. Each species may respond to fire in a different way, leading to varying degrees of mortality and regrowth. Thus, it is to be expected that significant changes in structure may occur within this cover type.

Silver Sagebrush-Grass Cover Type

This type is comprised of an overstory of silver sagebrush and an understory of grasses and forbs. All of the unburned sites had at least some silver sagebrush present. Our study shows that burning generally reduces silver sagebrush density, but that it is not eliminated from a site. Thus, changes in structure within this cover type are mostly dependent on the canopy cover of silver sagebrush on a site at some time following a fire.

The cover type was represented on 11 unburned/burned sites (Table 40). Of these, the structure class had changed on 6 of the burned sites.

Juniper-Grass Cover Type

This type is comprised of an overstory of juniper and an understory of grasses and forbs. Low to mid shrubs are generally present beneath the juniper. All of the unburned sites had at least some juniper present, usually in dense stands. Our study shows that juniper is especially vulnerable to fire. Little if any juniper remained on the burned sites. Thus, changes in structure within this cover type are to be expected.

The cover type was represented on 7 unburned/burned sites (Table 41). Of these, the structure class had changed on all of the burned sites. Juniper stands within the Northern Mixed Prairie provide important security areas and bedding sites for mule deer and elk. Loss of the juniper and the unique structure that it provides may be detrimental to these big game species.

Greasewood-Grass Cover Type

This cover type occurs mostly in drainage bottoms where soils are highly saline. Greasewood generally dominates the site, with grasses and forbs present in the understory. Our study shows that greasewood readily sprouts following a fire.

The cover type was represented on 3 unburned/burned sites (Table 42). Two sites had an Open Herbland/Scattered Shrub Phase structure before burning. One of these was an Open Herbland 4 years post-burn, the other had returned to the original structure within 6 years following the fire. The third unburned site had a Mixed Shrub/Mixed Herbaceous structure that changed to an Open Herbland/Scattered Shrub Phase 9 years after it was burned.

Influence of Fire on Vegetation Structure

Ninety-four different sites, which included 8 different rangeland cover types, were studied. Vegetation structure class was found to change on 61.7% of these sites following a wildfire. Structure change occurred mostly on those sites where shrubs were present. Certain shrub species were more susceptible to fire mortality than others. For example, fires mostly killed big sagebrush, common juniper and Rocky Mountain juniper. Other sprouting -shrub species were somewhat reduced by fire; they were slow in returning to pre-burn canopy coverage. Greasewood recovers quickly after burning, so that the pre-burn structure is attained within a very few years.

Table 35. Vegetation structure on unburned and burned Wheatgrass-Grama-Needlegrass cover type.

Unburned Site	Burned Paired Site	Age of Burn (Years)
Closed Herbland	Closed Herbland	1
Closed Herbland	Closed Herbland	1
Closed Herbland	Closed Herbland	2
Closed Herbland	Closed Herbland	4
Closed Herbland	Closed Herbland	12
Closed Herbland	Closed Herbland/Scattered Shrub Phase	20
Open Herbland	Open Herbland	2
Open Herbland	Open Herbland	3
Open Herbland	Open Herbland	4
Open Herbland	Open Herbland	4
Open Herbland	Open Herbland	4
Open Herbland	Open Herbland	5
Open Herbland	Open Herbland	6
Open Herbland	Open Herbland	8
Open Herbland	Open Herbland	8
Open Herbland	Open Herbland	8
Open Herbland	Open Herbland	9
Open Herbland	Closed Herbland	2
Open Herbland	Closed Mixed Herbland	5
Open Herbland	Open Herbland/Scattered Shrub Phase	4
Closed Herbland/Scattered Shrub Phase	Closed Herbland/Scattered Shrub Phase	5
Closed Herbland/Scattered Shrub Phase	Closed Herbland	12
Open Herbland/Scattered Shrub Phase	Open Herbland	9

Table 36. Vegetation structure on unburned and burned Wheatgrass cover type.

Unburned Site	Burned Paired Site	Age of Burn (Years)
Open Herbland	Open Herbland	1
Open Herbland	Open Herbland	7
Open Herbland	Open Herbland	17
Open Herbland/Scattered Shrub Phase	Open Herbland	3
Open Herbland/Scattered Shrub Phase	Open Herbland	8
Open Herbland/Scattered Shrub Phase	Open Herbland	11
Closed Herbland/Scattered Shrub Phase	Open Herbland/Scattered Shrub Phase	11

Table 37. Vegetation structure on unburned and burned Big Sagebrush - Grass cover type.

Unburned Site	Burned Paired Site	Age of Burn (Years)
Open Herbland/Scattered Shrub Phase	Open Herbland	1
Open Herbland/Scattered Shrub Phase	Open Herbland	1
Open Herbland/Scattered Shrub Phase	Open Herbland	3
Open Herbland/Scattered Shrub Phase	Open Herbland	4
Open Herbland/Scattered Shrub Phase	Open Herbland	4
Open Herbland/Scattered Shrub Phase	Open Herbland	4
Open Herbland/Scattered Shrub Phase	Open Herbland	5
Open Herbland/Scattered Shrub Phase	Open Herbland	5
Open Herbland/Scattered Shrub Phase	Open Herbland	8
Open Herbland/Scattered Shrub Phase	Open Herbland	9
Open Herbland/Scattered Shrub Phase	Open Herbland/Scattered Shrub Phase	5
Open Herbland/Scattered Shrub Phase	Open Herbland/Scattered Shrub Phase	8
Open Low Shrub/ Mixed Herbaceous	Open Herbland/Scattered Shrub Phase	4
Open Low Shrub/ Mixed Herbaceous	Open Herbland/Scattered Shrub Phase	17
Open Low Shrub/Mixed Herbaceous	Closed Herbland	10
Open Low Shrub/ Mixed Herbaceous	Open Herbland	14
Mixed Shrub/Mixed Herbaceous	Open Herbland	4
Mixed Shrub/Mixed Herbaceous	Open Herbland/Scattered Shrub Phase	10
Mixed Shrub/Mixed Herbaceous	Open Herbland/Scattered Shrub Phase	12
Closed Mixed Herbland/Scattered Shrub Phase	Closed Mixed Herbland/Scattered Shrub Phase	5
Closed Herbland/ Scattered Shrub Phase	Open Herbland	16
Open Herbland	Open Herbland/Scattered Shrub Phase	4
Open Mid Shrub	Open Herbland	12

Table 38. Vegetation structure on unburned and burned Fescue Grassland cover type.

Unburned Site	Burned Paired Site	Age of Burn (Years)
Open Herbland/Scattered Shrub Phase	Open Herbland	5
Open Herbland	Open Herbland	13
Open Herbland	Open Herbland	18
Open Herbland	Open Herbland/Scattered Shrub Phase	18

Table 39. Vegetation structure on unburned and burned Mixed Shrub - Grass cover type.

Unburned Site	Burned Paired Site	Age of Burn (Years)
Closed Mid Shrub	Closed Mid Shrub	10
Closed Tall Shrub	Mixed Shrub/Mixed Herbaceous	15
Closed Tall Shrub	Mixed Shrub/Mixed Herbaceous	16
Open Mid Shrub	Open Mid Shrub	1
Open Tall Shrub	Open Herbland	12
Open Tall Shrub	Open Herbland/ Scattered Shrub Phase	12
Open Tall Shrub	Open Herbland/ Scattered Shrub Phase	17
Open Low Shrub/Mixed Herbaceous	Open Low Shrub/Mixed Herbaceous	1
Open Low Shrub/Mixed Herbaceous	Open Herbland/ Scattered Shrub Phase	2
Open Low Shrub/Mixed Herbaceous	Open Low Shrub/Mixed Herbaceous	3
Mixed Shrub/Mixed Herbaceous	Open Herbland/ Scattered Shrub Phase	2
Mixed Shrub/Mixed Herbaceous	Closed Low Shrub/Mixed Herbaceous	3
Mixed Shrub/Mixed Herbaceous	Mixed Shrub/Mixed Herbaceous	12
Open Herbland/Mixed Shrub Phase	Open Herbland	6
Open Herbland/Mixed Shrub Phase	Open Herbland	12
Open Herbland/Mixed Shrub Phase	Open Herbland/Mixed Shrub Phase	16

Table 40. Vegetation structure on unburned and burned Silver Sagebrush – Grass cover type.

Unburned Site	Burned Paired Site	Age of Burn (Years)
Open Herbland/Scattered Shrub Phase	Open Herbland/Scattered Shrub Phase	5
Open Herbland/Scattered Shrub Phase	Open Herbland	8
Open Herbland/Scattered Shrub Phase	Open Herbland/Scattered Shrub Phase	10
Open Herbland/Scattered Shrub Phase	Open Herbland	12
Open Herbland/Scattered Shrub Phase	Open Herbland/Scattered Shrub Phase	13
Closed Herbland/Scattered Shrub Phase	Closed Herbland/Scattered Shrub Phase	9
Closed Herbland/Scattered Shrub Phase	Open Herbland/Scattered Shrub Phase	22
Open Low Shrub/Mixed Herbaceous	Open Herbland	3
Mixed Shrub/Mixed Herbaceous	Open Herbland/Scattered Shrub Phase	4
Open Herbland	Open Herbland	10
Open Herbland	Closed Mixed Herbland/Scattered Shrub Phase	18

Table 41. Vegetation structure on unburned and burned Juniper – Grass cover type.

Unburned Site	Burned Paired Site	Age of Burn (Years)
Open Tall Shrub	Open Herbland	1
Open Tall Shrub	Open Herbland	1
Open Herbland/Scattered Shrub Phase	Closed Mixed Herbland	4
Open Herbland/Scattered Shrub Phase	Open Herbland	4
Open Herbland/Scattered Shrub Phase	Open Herbland	4
Open Herbland/Scattered Shrub Phase	Open Herbland	6
Open Herbland/Scattered Shrub Phase	Open Herbland	6

Table 42. Vegetation structure on unburned and burned Greasewood – Grass cover type.

Unburned Site	Burned Paired Site	Age of Burn (Years)
Open Herbland/Scattered Shrub Phase	Open Herbland	4
Open Herbland/Scattered Shrub Phase	Open Herbland/Scattered Shrub Phase	6
Mixed Shrub/Mixed Herbaceous	Open Herbland/Scattered Shrub Phase	9

EFFECT OF FIRE ON COVER TYPE CLASSIFICATION

Cover Type Classification

Vegetation maps at various scales often delineate the vegetation that exists on the site at one point in time. The vegetation present on a site may approximate that of the potential, undisturbed vegetation, or display a multitude of variations due to past management, fire or natural disturbances (Shiflet, ed. 1994). Cover types are classified based on the vegetation that exists on a site. One objective of our study was to determine if fire affects the vegetation sufficiently to cause a cover type change. To do this, we classified the cover type of each pair of unburned and burned macroplots. Table 43 summarizes each cover type and the response of cover type to burning (no change, type change). Data were grouped by year-classes to provide an insight into changes over time following a fire. In most comparisons, sufficient data were available to provide for four age-classes (1-2, 3-5, 6-10, and > 10 years postfire). No burns were older than 10 years on Juniper-Grass and Greasewood-Grass cover types; thus, three age-classes are reported.

Wheatgrass Cover Type

The Wheatgrass cover type occurred on 7 unburned sites. No type change occurred on 4 burned sites 1-10 years after they were burned. On 3 sites where the fire had occurred more than 10 years prior to our study, 1 site had no type change, 1 site changed to a Wheatgrass-Grama type, and 1 site changed to a Mixed Shrub-Grass type.

Big Sagebrush Cover Type

The Big Sagebrush-Grass cover type was studied at 23 burned sites. Of these, only 3 (3-5 years of age) did not undergo a type change. The fires on these sites left most of the big sagebrush undamaged. Type changes occurred on the remaining 20 burned sites where the big sagebrush was killed. Current types include Wheatgrass-Grama-Needlegrass, Wheatgrass, Wheatgrass-Needlegrass, and Wheatgrass-Grama. Since big sagebrush does not possess underground buds, it cannot sprout and regrow after fire kills the aboveground plant tissue. The Big Sagebrush-Grass cover type has evidently become more widespread with fire suppression. As wildfires burn across this cover type, it appears to revert to one of the more-natural grass cover types.

Silver Sagebrush-Grass Cover Type

The Silver Sagebrush-Grass cover type was studied on 11 burned sites. Ten of the sites did not undergo a type change following burning. Silver sagebrush disappeared from 1 site following the fire, allowing a cover type change to Wheatgrass-Grama-Needlegrass. A fire generally kills some silver sagebrush plants. However, it is unusual for all of the plants to die following a wildfire. We were unable to determine why the species remained on 10 sites but disappeared on 1 site.

Juniper-Grass Cover Type

Seven sites were studied within this type. Common juniper and Rocky Mountain juniper were killed by wildfires. All of the burned sites were converted to Wheatgrass and Wheatgrass-Needlegrass cover types.

Ponderosa pine-Shrubland Cover Type

Five sites within this cover type were studied. Three of these had a light understory burn and did not undergo a type change. On 2 sites where crown fires occurred, the ponderosa pine was killed, leading to type changes to Wheatgrass-Grama-Needlegrass on 1 site and Mixed Shrub-Grass on the other.

Cover Types That Did Not Undergo Type Change

No type change occurred for Wheatgrass-Grama-Needlegrass (23 sites), Fescue Grasslands (4 sites), Mixed Shrub-Grass (16 sites) and Greasewood-Grass (3 sites) cover types.

Table 43. Cover type classification in response to burning.

Unburned Cover Type	Age Class	Burned Sites: No Change	Burned Sites: Type Change
Wheatgrass–Grama–Needlegrass	1-2 years	5[1/]	0[2/]
	3-5 years	9	0
	6-10 years	6	0
	> 10 years	3	0
Wheatgrass	1-2 years	1	0
	3-5 years	1	0
	6-10 years	2	0
	> 10 years	1	Wheatgrass–Grama (1) Mixed Shrub–Grass (1)
Big Sagebrush – Grass	1-2 years	0	Wheatgrass–Grama–Needlegrass (1) Wheatgrass (1)
	3-5 years	3	Wheatgrass–Needlegrass (1) Wheatgrass–Grama–Needlegrass (4) Wheatgrass (3)
	6-10 years	0	Wheatgrass–Grama–Needlegrass (3) Wheatgrass–Grama (1) Wheatgrass (1)
	>10 years	0	Wheatgrass–Needlegrass (1) Wheatgrass–Grama–Needlegrass (2) Wheatgrass (2)
Fescue Grasslands	1-2 years	-[3/]	-
	3-5 years	1	0
	6-10 years	0	0
	>10 years	3	0
Mixed Shrub – Grass	1-2 years	4	0
	3-5 years	2	0
	6-10 years	1	0
	>10 years	9	0

Table 43. continued

Unburned Cover Type	Age Class	Burned Sites: No Change	Burned Sites: Type Change
Silver Sagebrush-Grass	1-2 years	-	-
	3-5 years	3	0
	6-10 years	3	Wheatgrass-Grama Needlegrass (1)
	> 10 years	4	0
Juniper–Grass	1-2 years	0	Wheatgrass–Needlegrass (2)
	3-5 years	0	Wheatgrass (3)
	6-10 years	0	Wheatgrass–Needlegrass (2)
Greasewood–Grass	1-2 years	-	-
	3-5 years	1	0
	6-10 years	2	0
Ponderosa Pine–Shrubland	1-2 years	1	0
	3-5 years	0	Wheatgrass-Grama Needlegrass (1)
	6-10 years	-	-
	>10 years	2	Mixed Shrub–Grass (1)

1/ Number of sites on which no change in cover type occurred following a fire.
2/ Number of sites on which a cover type change occurred following a fire.
3/ No sites were sampled that fell within this age class.

FIRE EFFECTS ON MAJOR PLANT SPECIES

This section is presented as a synopsis of the following M.S. thesis: Kruger, Sarah. 2001. Effects of Fire on Range Plant Species in the Northern Mixed Grass Prairie. 156 pp.

The main focus of this thesis is to study the effects of fire on grass and shrub plant communities in the Northern Mixed Prairie and to assess the effectiveness of fire as a management tool in: 1) promoting or sustaining the growth of desirable forage species, and 2) reducing the presence of undesirable plants, including woody vegetation, invasive weeds, and plants of minimal forage value.

Objectives

Objectives are to describe the effects of fire within the Northern Mixed Grass Prairie through measurement of relative percent cover of individual plant species on burned sites compared to similar unburned areas. Furthermore, plant succession paths will be ascertained by categorizing areas based on burn dates. The objective is to determine whether fire causes immediate and/or long-term changes in Northern Mixed Grass Prairie communities based on individual plant species' response to fire. Specific objectives are to determine 1) immediate effects of fire on individual plant species, expressed as relative cover values for selected species within the major range types and 2) long-term effects of fire on plant species; i.e. the successional path a species undergoes following fire, depicted as changes in plant species cover over time.

Hypotheses were developed to test the following: 1) whether a significant difference occurred in average cover values of individual plant species between an area burned by wildfire and an adjacent unburned area, and 2) whether a significant difference occurred in average cover values of individual plant species between burned sites of different age classes.

Materials and Methods

Field Studies

Field studies were conducted over a wide array of previously burned sites in the Northern Mixed Grass Prairie to obtain information about how a changing fire regime affects plant species composition and ground cover. I focused on grassland and shrubland range types in the upland landscapes. Each burned site was matched with an adjacent and similar unburned (control) site to compare any differences between the two. By comparing burned versus adjacent unburned sites, the effects of fire on plant communities and individual plant communities could be isolated. Topographic and climatic features were controlled through a matched-site process of using a similar unburned site adjacent to the burned site where plot data were collected, and by covering a vast region. The burns occurred from the years 1978-2000.

Plot Establishment and Data Collection

Plot establishment and data collection methods were employed using Ecodata (USDA Forest Service, 1987) procedure guidelines. A 1/10 acre macroplot (66' X 66') was established on each burned site and adjacent unburned site. Vegetative characteristics and topographic features were similar between each paired burned/unburned match. As each set of paired plots was sampled in the same general vicinity, it is assumed that climate and soils remain constant.

Within each macroplot five transect lines were established, each line having 5 microplots spaced at 12-foot intervals. This pattern was repeated in all plots. The microplots, each a 10" x 20" rectangle, were used to obtain canopy cover values for all plant species. Cover values are expressed as percentages. Canopy cover class for each species was recorded using the following coded system:

Table 44. Percent Canopy Cover Classes

Code	Range of Class
0	0%
T	0.1 < 1%
P	1 < 5%
1	5 < 15%
2	15 < 25%
3	25 < 35%
4	35 < 45%
5	45 < 55%
6	55 < 65%
7	65 < 75%
8	75 < 85%
9	85 < 95%
F	95 – 100%

T = present in trace amounts
P = present in the 1-5% range
F = present at or near full coverage

Microplot range class values were entered into a Microsoft Excel (2000) program using the median number of the respective range class in which that species occurred. Average canopy cover for each species in a transect was determined using Microsoft Excel by calculating the sum of the percent cover values of the microplots along that transect and dividing this sum by five, (the number of microplots in a transect).

Burn Status

All plots analyzed were classified into range types using a dichotomous key based on dominant species present (DeVelice et al. 1991). The range types included in this thesis are those classified as “shrub types” and “grass types.” Within these range types, I further classified plots based on their burn status. Each plot falls into one of the following five categories: 1) unburned, 2) burned 1 year prior to year of study, 3) burned 2-5 years prior to year of study, 4) burned 6-15 years prior to year of study, 5) burned 15+ years prior to year of study. This method of categorization allows a comparison between burned and unburned sites, and between sites in varied successional stages following a fire.

Cover Values for Individual Plant Species

Average cover values for individual plant species were calculated from microplot cover data. Total cover in a microplot does not equal 100 percent as layering of vegetation is possible and can give a total cover value of greater than 100 percent; conversely, some microplots had cover values of less than 100 percent due to a less dense stand of vegetation, minimal canopy layering, and a heightened presence of bare ground.

Cover values are represented in the data as average canopy cover per transect. This computation was made for each species by averaging the canopy cover of that species over the five microplots occurring in a single transect. The resulting number, rounded to two decimal places, was then plotted as one point in a boxplot. This process was performed for all selected species within both unburned and burned plots occurring in grass and shrub communities. If a species was present in a macroplot, average percent cover per transect was calculated for all five of the transects in that macroplot, whether the species occurred in each transect or not. Transects are categorized using the burn status categories. Each burned plot has an unburned match. If a species was not present in either the burned or control plot, average cover values were not calculated for that paired plot. If a species was present in either the burned plot, or the unburned match, average cover values were noted for both the five burned transects and the five unburned transects in order to compare the two. Zeroes were entered if the species was not found along one of these transects.

Data Analysis

Data for species was recorded, sorted, and calculated in a Microsoft Excel spreadsheet (2000). Statistical analysis was performed in the statistical package SPSS 10.00 for Windows (2000). Within SPSS, data were re-entered in order to create boxplots. Boxplots are an effective method of depicting non-normally distributed data, as they show the general range of data (depicted by brackets, which exclude outliers and extreme values), the 50th percentile range (shaded area of boxplot), as well as the median of the data set (horizontal bar), and any outliers and extreme values (denoted by * in the graphs). However, outliers were excluded from the graphs in this thesis, as the range, 50th percentile, extreme values, and median were adequate in displaying the data.

Graphs for species cover were made for each burn category using boxplots to represent the data for comparison analysis. Boxplots only show canopy cover values for transects in which the species occurred. Values of zero (representing transects where the species was not found) were not entered to avoid skewing the data. Tables follow each boxplot, and show the number of transects each species occurred in compared to the total number of transects in that burn category.

The boxplots allow a visual analysis of average cover values for individual species on both burned and unburned sites, and are categorized based on the age class of the burn. Differences between burned and unburned areas can be evaluated, as well as differences between age classes. Data presentation in the boxplots is arranged by species, burn status, and burn date. Desirable forage species are represented as one category, while undesirable range plants are broken into two categories: those with low canopy cover values (fringed sage, Japanese brome, and prickly pear cactus), and those with high canopy cover values (silver sagebrush, big sagebrush, greasewood, and clubmoss). This allows better visual comparison, as some of the undesirable range plants occur in such high densities that plotting the species in the same graph causes those values for species that occur in low densities to become too compressed.

These three species groups are separated into burned/unburned categories and are shown for each age class. If a species was not present in a particular age class, a value of zero was entered so that this could be noted graphically as well. In addition to plots designated by age class, a boxplot combining all age classes of unburned data, as well as a boxplot combining all age classes of burned data is included.

Hypothesis Testing

The statistical package SPSS 10.0 Windows version (2000) was used to test the data in this study. To determine if there is a significant difference in average cover values of each species between the different burn treatments (burned or unburned) in each of the age groups, a matched pair t-procedure was applied by means of using a one-sample t-test on the observed differences between the unburned and burned canopy cover values in the matched plots. A statistical one-sample t-test was performed on the difference calculation in average cover values between burned and unburned transects for each age class. The difference calculation is the average cover value for a species in a burned transect subtracted from the average cover value for that species in the matched unburned transect. The average cover value for transect one of the burned plot was compared to the average cover value for transect one in the unburned plot; the same is applicable for each numbered transect. The differences computation in average cover values for each species between each unburned and burned paired transect organizes data into a normal distribution so that a t-test can be used to analyze the data and determine if the mean difference in species cover between burned and unburned areas is indeed significant. Using a 95 percent confidence interval, and a significance value of ($p<.05$), the t-test compares the mean of the difference computation to zero in order to determine a significant difference in either direction from the mean.

In order to determine if there is a significant difference in individual species cover values between each successional age class of burns an independent samples t-test was performed. The same p-value and confidence interval were used as in the burn vs. unburned t-tests. A pre-test for equal variance was computed. If variance in species cover values between successional stages is equal then the standard t-test was used; if the variance is unequal, the Welch's test (the t-test for unequal variances) for significance was used.

Results

Data are represented in the following boxplot figures to allow visual analysis of cover values for selected plant species. Comparisons are presented for each category (desirable and undesirable species) based on burn status (unburned and burned) and age class of burn. Significance tests for each species are presented in accompanying tables.

Average Cover Values for Transects within All Burned and Paired Unburned Plots

A comparison of desirable forage species average cover values between all burned and unburned plots illustrates much similarity (Fig. 10). Canopy cover values tend to fall in the 1-5 percent range. Extremes include low values of near zero, and high values of 10 or greater.

A comparison of "n" values of individual plant species (Table 45) gives an idea of how constant each species is across the grass and shrub communities that were studied. A high "n" value shows that particular species is found in a high number of transects throughout the study area.

Table 45. Total number of transects (“n” values) in which each species occurred within all unburned and burned grass and shrub type plots; maximum total occurrences possible (total number of transects studied in each category) is n = 310.

Species	Western wheat-grass	Bluebunch wheatgrass	Blue grama	Prairie Junegrass	Sandberg bluegrass	Green needlegrass	Crested wheatgrass
Unburned	228	75	129	157	88	64	10
Burned	219	63	163	160	105	82	14

Western wheatgrass, “n” value of 228, was present in nearly 74 percent of all evaluated unburned transects and nearly equally represented in the burned transects studied. On the other hand, crested wheatgrass, with an “n” values of 10 and 14, was present in only 3 percent of all evaluated unburned transects, and only 5 percent of all burned transects studied. Other species maintained constancy throughout the unburned

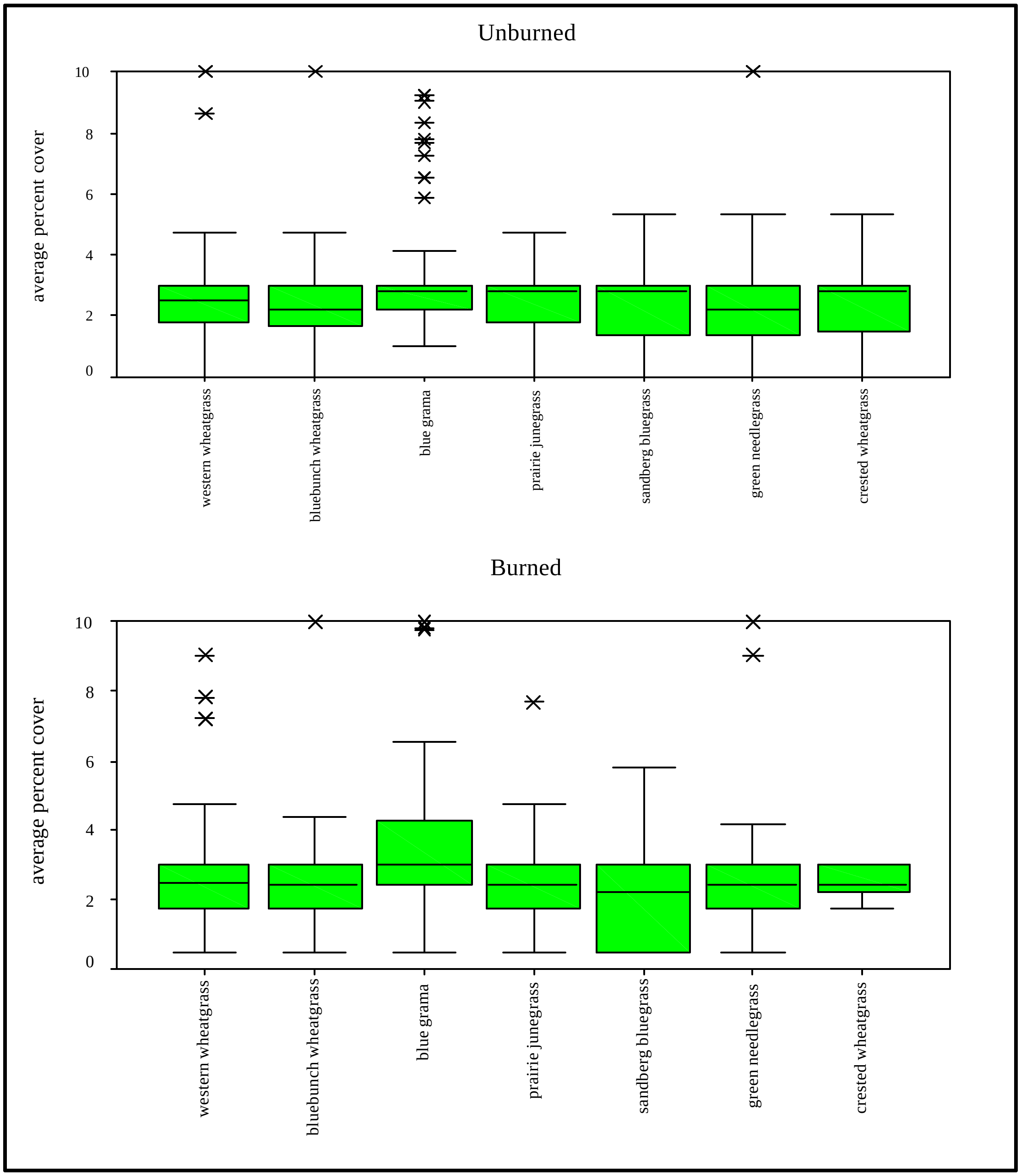


Figure 10. Average canopy cover values of desirable forage species per transect within all unburned and burned grassland and shrubland plots.

transects in a range of 21-51 percent. Bluebunch wheatgrass was found in slightly more unburned than burned transects. Blue grama, Sandberg bluegrass, and green needlegrass each tend to be more frequent on burned sites compared to unburned sites. Prairie Junegrass portrays almost identical frequency values in burned and unburned sites.

Canopy cover of undesirable range plants falling into the subshrub, forb, or grass status in burned and unburned grasslands and shrublands shows a range of 0-10 percent (Fig. 11). In the unburned sites, fringed sage shows average canopy cover values mainly in the 0-5 percent range, with extreme values in the 8-10 percent range. Fringed sage on burned sites has a greater general range of cover at 0-8 percent. Japanese brome shows cover values on unburned sites falling in the 0-7 percent range, while on burned sites, the range is slightly smaller (0-3 percent); however, on the burned sites, extreme canopy cover values near the 10 percent range. Prickly pear cactus, where found on burned and unburned sites, harbors cover values mainly in the 2-4 percent range, with low extreme values near 0 percent and high extreme values in the 8-10 percent range.

Undesirable species are found scattered throughout unburned grassland and shrub communities. Japanese brome holds the highest “n” value (n = 124), and thus was present in about 40 percent of all transects evaluated in the unburned grasslands and shrublands of the study area (Table 46). It was found in a similar amount (38 percent) of burned transects. Fringed sage appears to be present in near equal frequencies in unburned and burned areas (36 and 33 percent respectively). Prickly pear cactus was found in 13 percent of evaluated unburned transects and only 7 percent of the evaluated burned transects.

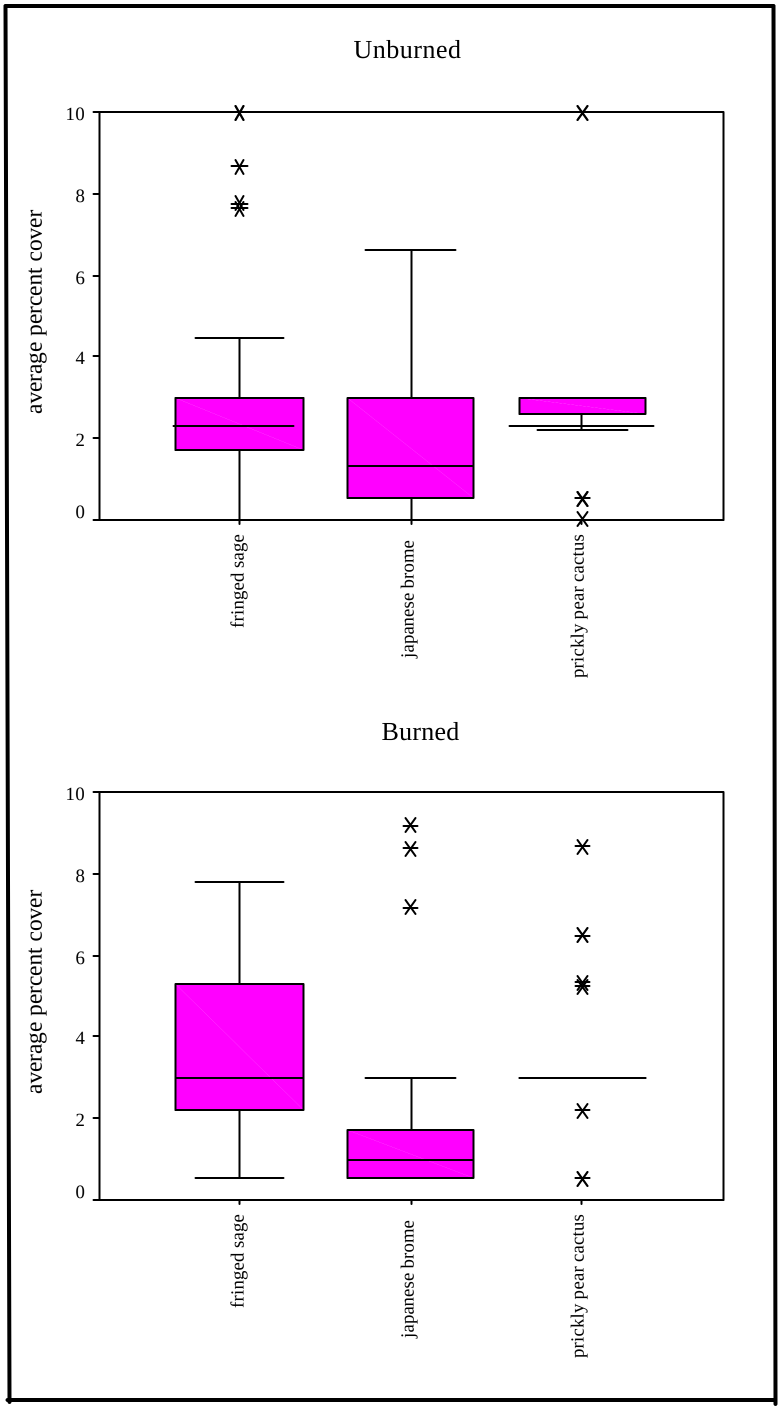


Figure 11**.** Average canopy cover values of undesirable plant species exhibiting low canopy cover values per transect within all unburned and burned grassland and shrubland plots.

Table 46. Total number of transects ("n" values) in which each species occurred within all unburned and burned grassland and shrubland plots; maximum total occurrences possible (total number of transects studied in each category) is n = 310.

Species	Fringed sage	Japanese brome	Prickly pear cactus
Unburned	112	124	39
Burned	101	119	23

Canopy cover of undesirable range plants, including clubmoss, big sagebrush, greasewood, and silver sagebrush in unburned grasslands and shrublands falls into the 0-75 percent range (Fig. 12). Each of these species harbors greater canopy cover values in the unburned areas compared to the adjacent burned areas.

Big sagebrush occurred in 31 percent of the unburned transects evaluated, and only 5 percent of the adjacent burned transects (Table 47). Clubmoss was found in 28 percent of all unburned transects, and in 21 percent of the burned transects. Silver sagebrush was found in nearly exactly the same amount of burned transects as unburned transects (about 15 percent). Greasewood, although found only in a total of twelve of the transects studied, was present in twice as many burned transects as unburned matches.

Table 47. Total number of transects ("n" values) in which each species occurred within all unburned and burned grassland and shrubland plots; maximum total occurrences possible (total number of transects studied in each category) is n = 310.

Species	Silver sagebrush	Big sagebrush	Greasewood	Clubmoss
Unburned	48	97	4	86
Burned	46	14	8	65

Average Cover Values for Transects within One-Year-Old Burns and Paired Unburned Plots

. Average canopy cover values of desirable range forage species fall within the 0-5 percent range in the unburned plots compared to a 0-7 percent range in adjacent plots that burned one year prior to the year of study (Fig. 13).

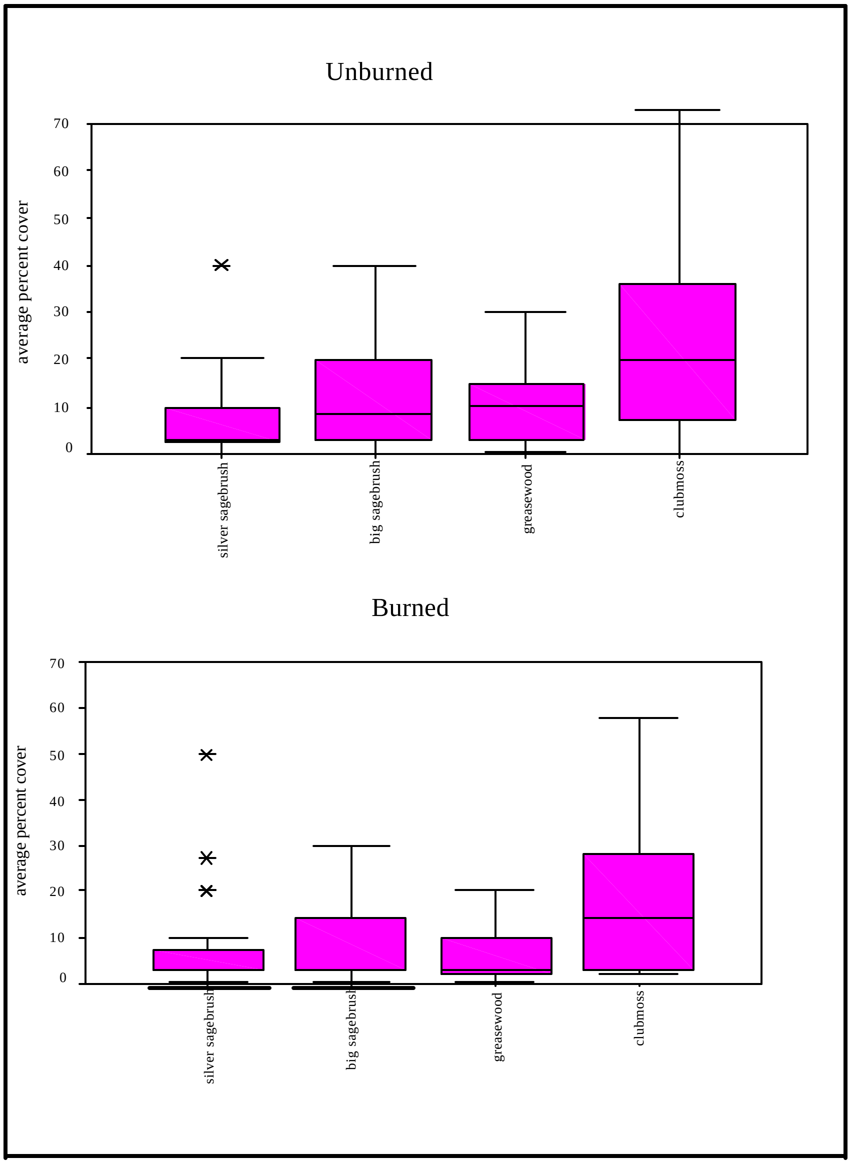


Figure 12. Average canopy cover values of undesirable plant species exhibiting high canopy cover values per transect within all unburned and burned grassland and shrubland plots.

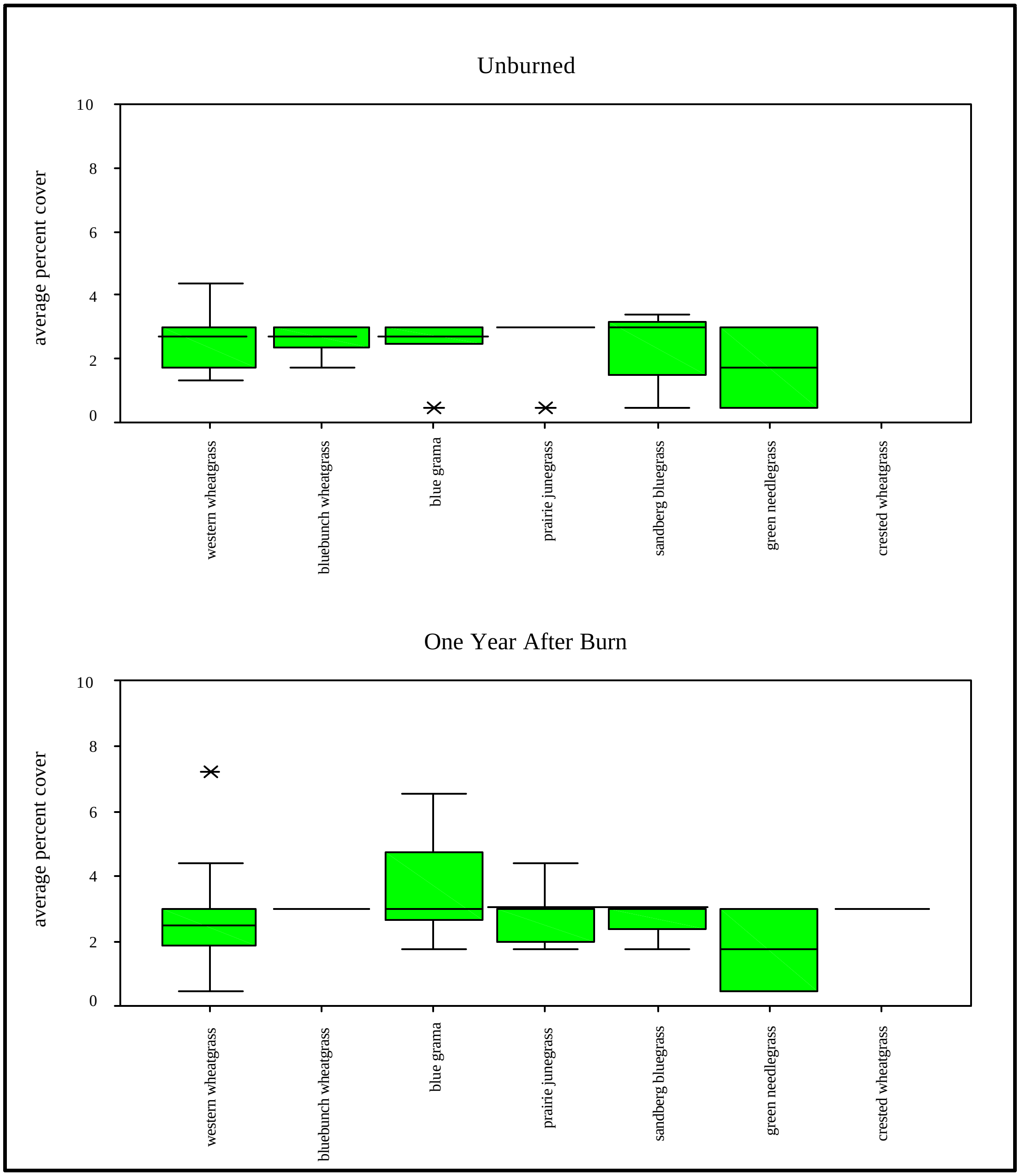


Figure 13. Average canopy cover values of desirable forage species per transect within unburned plots compared to paired plots that burned one year previous to the year of study.

Western wheatgrass appears to maintain similar average cover values between one year old burns and adjacent unburned sites. However, in unburned sites the lower range bracket and the median are both higher values compared to matched burned sites. Bluebunch wheatgrass and green needlegrass average cover values appear to remain constant in the comparison between burned and unburned sites. Blue grama appears to increase in cover the year following a burn. Sandberg bluegrass and prairie Junegrass show little change in cover values the first year following fire; however, the overall ranges of percent cover for these two species increase on average in the first year following a burn. There is a lack of data for crested wheatgrass, so no comparison can be made.

Western wheatgrass, blue grama, and Sandberg bluegrass each were found in nearly constant frequency between unburned sites and adjacent sites that burned one year prior (Table 48). Western wheatgrass was present in 73 percent of the unburned transects and 67 of the burned transects. Blue grama was found in 30 percent of the unburned transects and 37 percent of the burned transects. Sandberg bluegrass was found in 23 percent of both burned and unburned transects. Prairie Junegrass was present in nearly twice as many burned transects compared to matched, unburned transects (57 and 30 percent, respectively). Bluebunch wheatgrass, green needlegrass, and crested wheatgrass were not present in an adequate number of transects to allow comparison.

Table 48. Total number of transects ("n" value) in which each species occurred within the unburned grass and shrub type plots and matched plots which burned one year prior to the year of study; maximum total occurrences possible (total number of transects studied in each category) is n = 30.

Species	Western wheatgrass	Bluebunch wheatgrass	Blue grama	Prairie Junegrass	Sandberg bluegrass	Green needlegrass	Crested wheatgrass
Unburned	22	3	9	9	7	2	0
Burned	20	1	11	17	7	5	1

Fringed sage and Japanese brome maintained equal canopy cover values (in the 0-3 percent range) between sites that burned one year prior and adjacent unburned sites (Fig 14). Prickly pear cactus maintains an equal range of canopy cover values between burned and unburned sites (0-3 percent); however, the 50^{th} percentile occupies a higher average cover bracket in the unburned sites compared to adjacent burned sites.

Thirty transects were studied in plots that burned one year prior, and also in matched, adjacent unburned plots (Table 49). Fringed sage was found in six of the thirty unburned transects (20 percent), and in eight of the thirty burned transects (27 percent). Cactus was present in 23 percent of the unburned transects and in only 7 percent of the matched burned transects. Japanese brome was found in about 43 percent of the unburned transects, and in nearly 47 percent of the burned matches.

Table 49**.** Total number of transects ("n" values) in which each species occurred within the unburned grass and shrub type plots that are matched to the plots which burned one year prior to the year of study; maximum total occurrences possible (total number of transects studied in each category) is n = 30.

Species	Fringed sage	Japanese brome	Prickly pear cactus
Unburned	6	13	7
Burned	8	14	2

Undesirable species found in unburned areas adjacent to one-year-old burns show cover values ranging from 0-30 percent (Fig. 15). In plots that burned one year prior to the year of study clubmoss illustrates a cover range of 0-55 percent compared to a smaller range of 0-30 percent in matched unburned plots. Big sagebrush, although found in the adjacent unburned plots (as illustrated above), was not present in any of the burned plots. Silver sagebrush, found in only one of the matched unburned transects was also not present in any of the burned transects. Greasewood is absent from both the burned and unburned plots in this class.

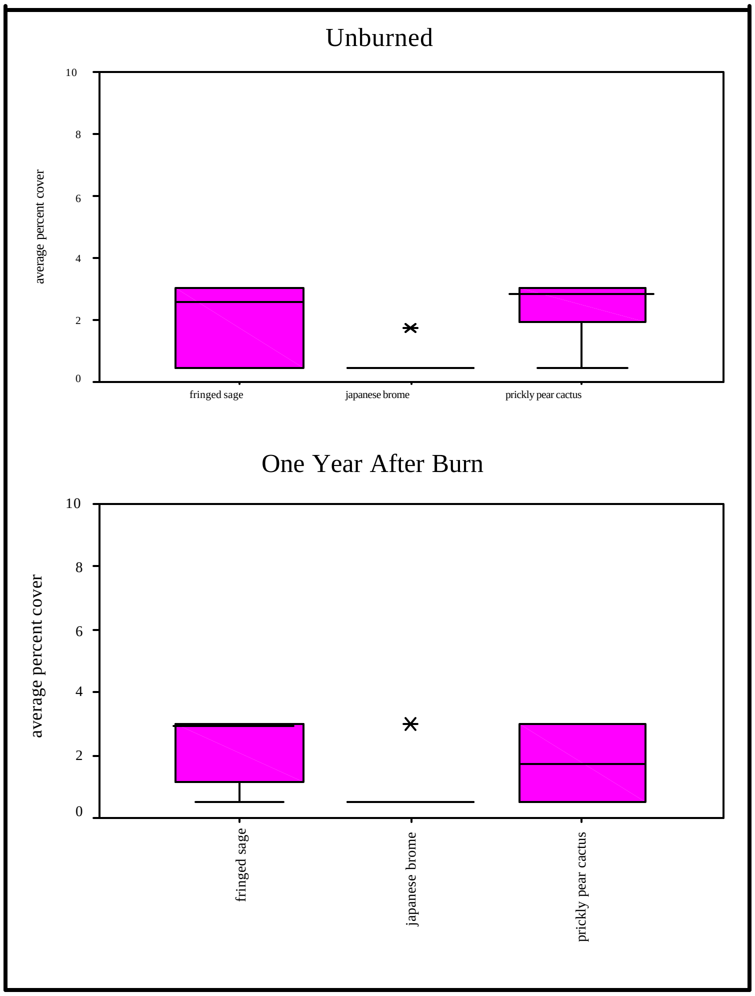


Figure 14. Average canopy cover values of undesirable forage species exhibiting low canopy cover values per transect within unburned plots compared to paired plots that burned one year previous to the year of study.

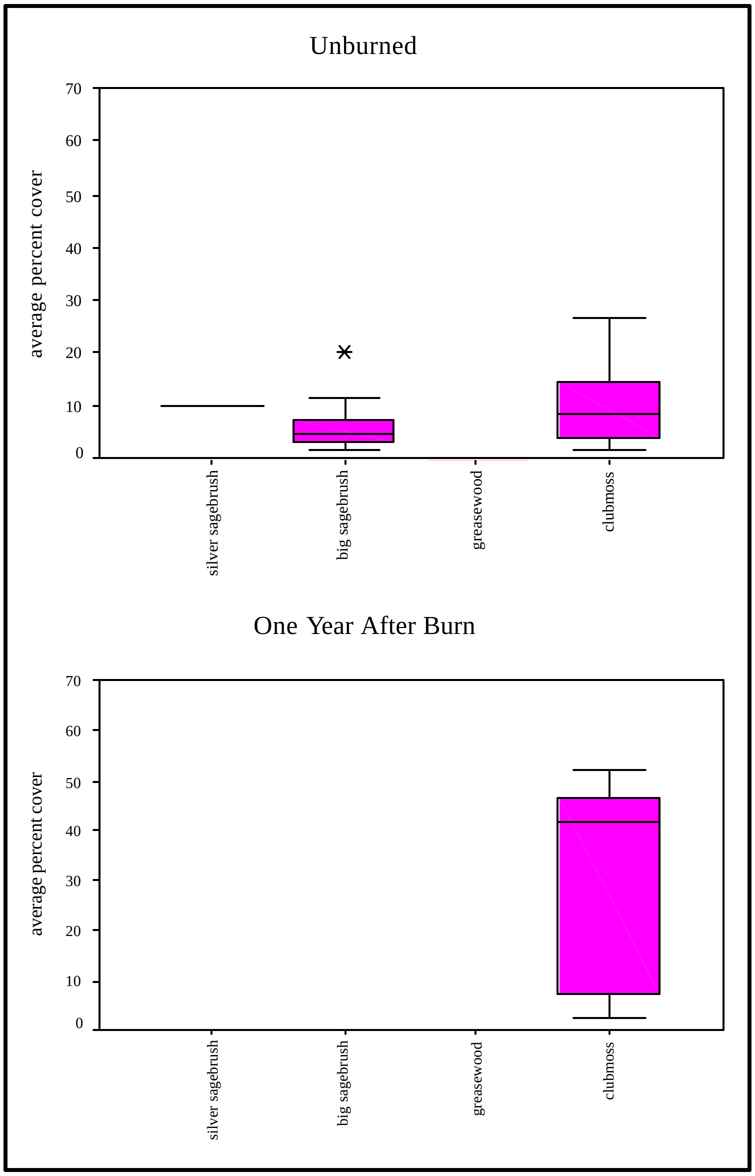


Figure 15. Average canopy cover values of undesirable forage species exhibiting high canopy cover values per transect within unburned plots compared to paired plots that burned one year previous to the year of study.

Comparing unburned sites to adjacent sites that burned one year prior (Table 50), big sagebrush was found in 30 percent of the unburned transects and in 0 percent of the burned transects. Clubmoss was present in 27 percent of the unburned transects and 23 percent of the burned transects. Silver sage was found in only one of the unburned transects and none of the burned matches. Greasewood was not present in any of the burned or unburned transects studied.

Table 50**.** Total number of transects ("n" values) in which each species occurred within the unburned grass and shrub type plots and matched plots that burned one year prior to the year of study; maximum total occurrences possible (total number of transects studied in each category) is n = 30.

Species	Silver sagebrush	Big sagebrush	Greasewood	Clubmoss
Unburned	1	9	0	8
Burned	0	0	0	7

Average Cover Values for Transects within Two- to Five-Year-Old Burns and Paired Unburned Plots

Desirable range forage plants occur in 2-5 year old burns and adjacent unburned sites in a cover values range of 0-6 percent (Fig. 16). Western wheatgrass and bluebunch wheatgrass show no change in cover values between burned and unburned sites. Blue grama, prairie Junegrass, Sandberg bluegrass, and green needlegrass each appear to increase slightly in cover two to five years following a burn. Crested wheatgrass' range of cover values increases two to five years following fire.

Desirable range forage plants occurring in transects within unburned plots (matched and adjacent to plots that burned two to five years prior to the year of study) were found in frequencies of 6-65 percent (Table 51). Western wheatgrass, bluebunch wheatgrass, blue grama, prairie Junegrass, green needlegrass, and crested wheatgrass were each found in approximately the same number of unburned transects compared to burned transects.

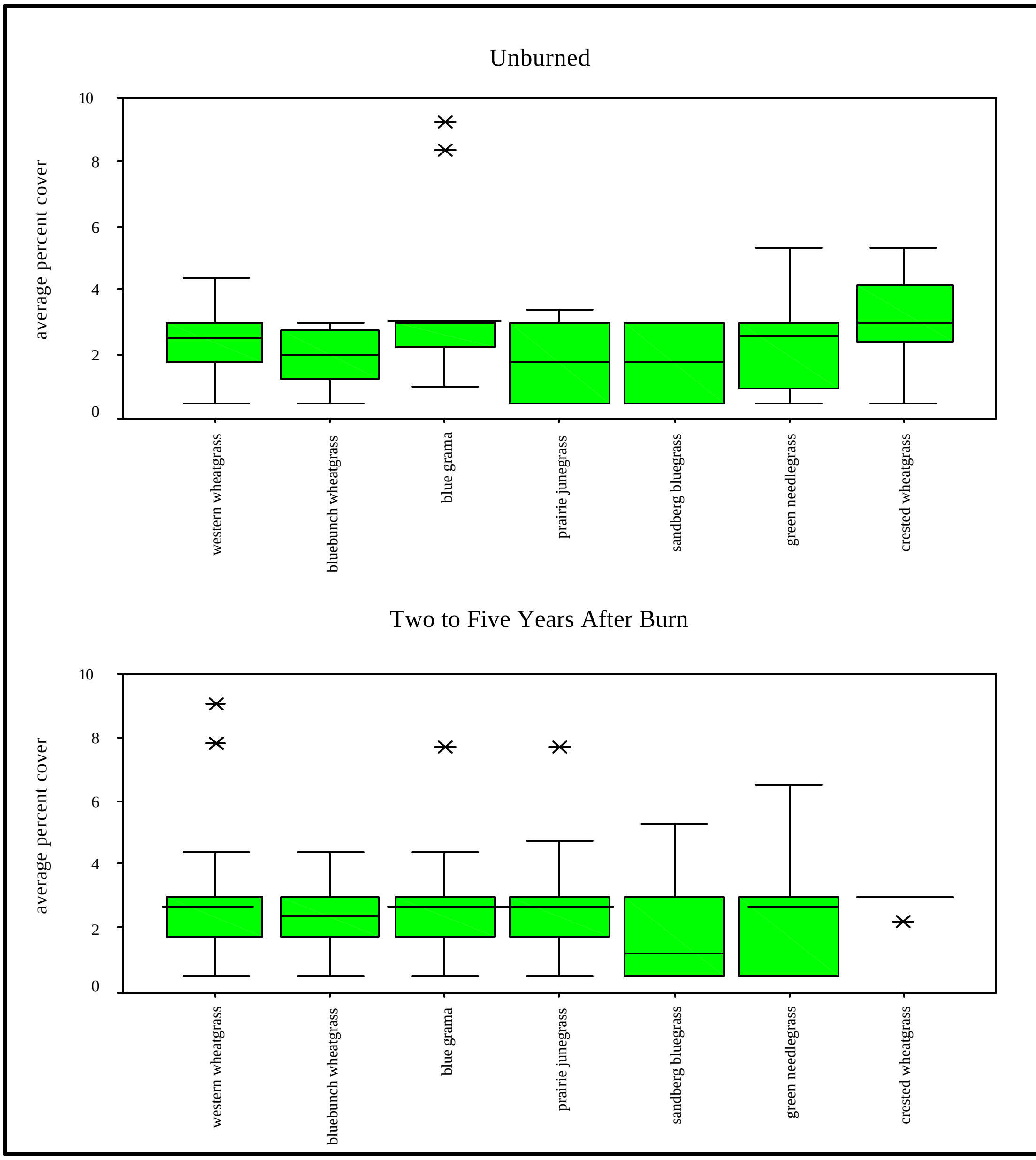


Figure 16. Average canopy cover values of desirable forage species per transect within unburned plots compared to paired plots that burned two to five years previous to the year of study.

Western wheatgrass was found most frequently (65-67 percent of the time). Bluebunch wheatgrass was found in 27-28 percent of the plots studied. Crested wheatgrass was found in only 6-8 percent of the evaluated transects. Sandberg bluegrass was found in twice as many burned transects (35 percent) compared to adjacent unburned transects (17 percent).

Table 51**.** Total number of transects ("n" values) in which each species occurred within the unburned grass and shrub type plots and matched plots which burned two to five years prior to the year of study; maximum total occurrences possible (total number of transects studied in each category) is n = 110

Species	Western wheatgrass	Bluebunch wheatgrass	Blue grama	Prairie Junegrass	Sandberg bluegrass	Green needlegrass	Crested wheatgrass
Unburned	72	31	60	54	19	28	7
Burned	74	30	62	59	38	26	9

In the two to five year period following fire, fringed sage appears to increase in cover (Fig. 17). Japanese brome also increases slightly following fire. Prickly pear cactus shows no apparent change in cover.

A total of 110 unburned transects, matched to an equal number of transects that burned two to five years prior to the year of study, were evaluated (Table 52). Prickly pear cactus was found in 11 percent of the unburned transects, and in about half as many (5 percent) of the burned transects. Fringed sage was found in nearly 35 percent of the unburned transects and in a similar 31 percent of the burned matches. Japanese brome was found in nearly 41 percent of the unburned transects compared to only 27 percent of the adjacent burned sites.

Table 52**.** Total number of transects ("n" values) in which each species occurred within the unburned grass and shrub type plots and matched plots which burned two to five years prior to the year of study; maximum total occurrences possible (total number of transects studied in each category) is n = 110.

Species	Fringed sage	Japanese brome	Prickly pear cactus
Unburned	38	45	12
Burned	34	30	6

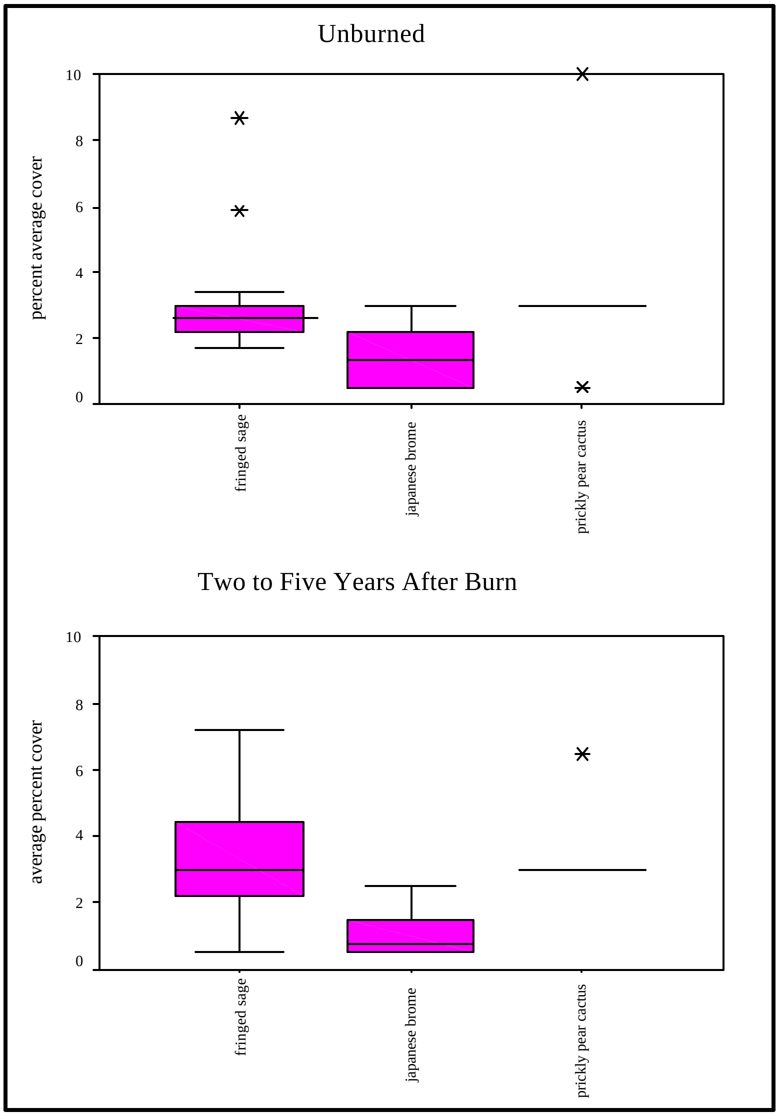


Figure 17**.** Average canopy cover values of undesirable plant species exhibiting low canopy cover values per transect within unburned plots compared to paired plots that burned two to five years previous to the year of study.

Silver sagebrush appears to increase slightly in the two to five year period following a burn (Fig. 18). Transects in unburned sites harbor big sagebrush in the 0-30 percent range. In burned areas, the number of big sagebrush plants was greatly reduced. However, due to incomplete burning of the site, a few sagebrush plants were left unharmed, and these exhibited canopy cover similar to sagebrush plants growing in unburned sites. Greasewood shows no change in cover value in the two to five years following a burn; however, only one transect was available in each of the burned and unburned categories, so a valid comparison is unavailable. Clubmoss appears to decrease substantially in two to five years following a fire; cover values decrease from the 0-75 percent range to a 0-40 percent range.

Silver sagebrush and greasewood were found in the same number of transects in the burned plots as the unburned matches, 10 percent and 1 percent respectively (Table 53). In the two to five year old burns, big sagebrush was found in only three of the burned transects compared to thirty six of the matched unburned transects. Clubmoss was found in about twice as many unburned transects compared to the burned matches.

Table 53**.** Total number of transects (“n” values) in which each species occurred within the unburned grass and shrub type plots and matched plots which burned two to five years prior to the year of study; maximum total occurrences possible (total number of transects studied in each category) is n = 110.

Species	Silver sagebrush	Big sagebrush	Greasewood	Clubmoss
Unburned	11	36	1	29
Burned	11	3	1	14

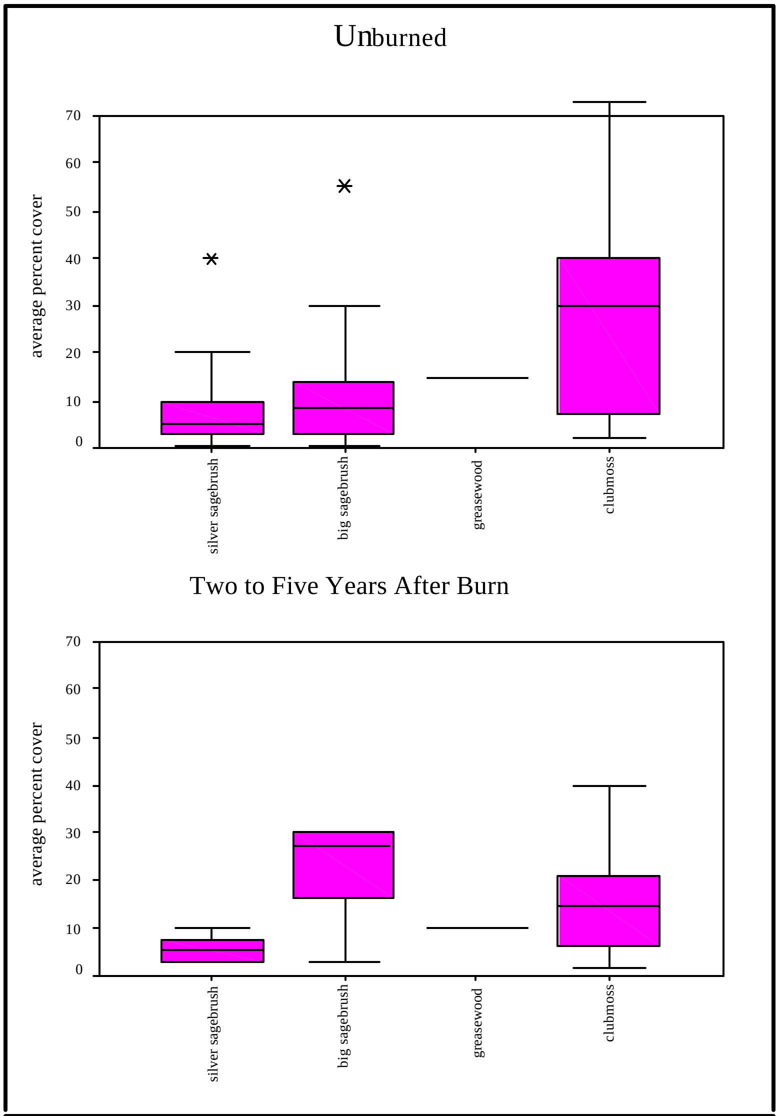


Figure 18. Average canopy cover values of undesirable forage species exhibiting high canopy cover values per transect within unburned plots compared to paired plots that burned two to five years previous to the year of study.

Average Cover Values for Transects within Six- to Fifteen-Year-Old Burns and Paired Unburned Plots

Western wheatgrass, blue grama, and prairie Junegrass each show an increase in average cover values in the 6-15 year period following fire (Fig. 19). Bluebunch wheatgrass, green needlegrass, and crested wheatgrass all maintain similar cover values between unburned sites and sites that burned 6-15 years prior. Sandberg bluegrass shows a slight decrease in cover in the 6-15 year period following fire.

Western wheatgrass is the most common plant, and was present in 78 percent of the unburned transects and 71 percent of matched burned transects (Table 54). Blue grama, prairie Junegrass, Sandberg bluegrass, and crested wheatgrass were found in a nearly equal number of unburned transects compared to burned matches. Bluebunch wheatgrass was present in slightly more unburned transects compared to burned matches. Green needlegrass was found in slightly fewer (23 percent) unburned transects compared to 28 percent of burned transects.

Table 54. Total number of transects ("n" values) in which each species occurred within the unburned grass and shrub type plots and matched plots which burned six to fifteen years prior to the year of study; maximum total occurrences possible (total number of transects studied in each category) is n = 125.

Species	Western wheatgrass	Bluebunch wheatgrass	Blue grama	Prairie Junegrass	Sandberg bluegrass	Green needlegrass	Crested wheatgrass
Unburned	98	33	50	68	48	29	3
Burned	89	26	51	65	47	35	4

Fringed sage shows no increase in average cover values in the 6-15 year period following fire (Fig. 20). Japanese brome appears to decrease in cover in the 6-15 year period following fire, while prickly pear cactus shows a slight increase in cover in this period following fire.

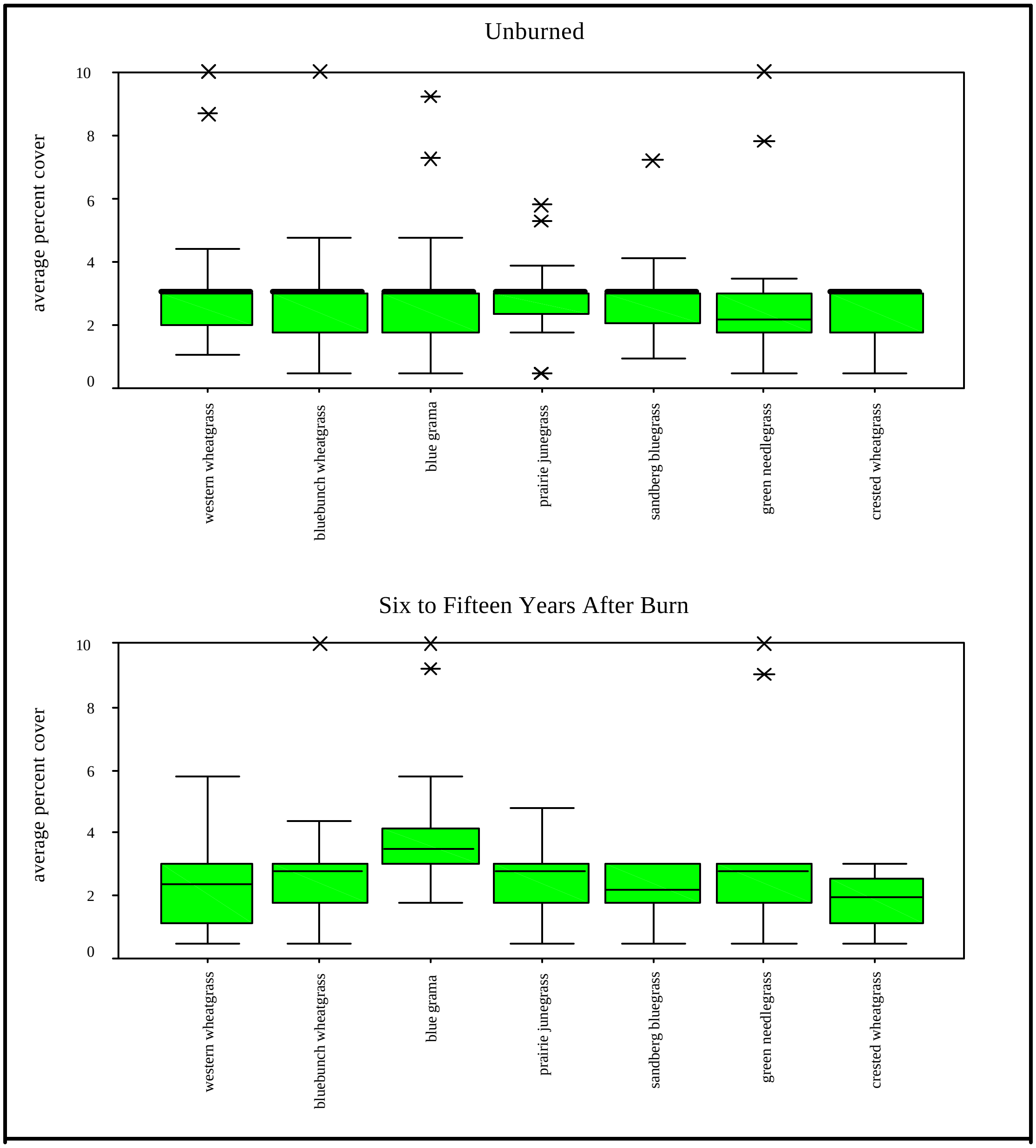


Figure 19. Average canopy cover values of desirable forage species per transect within unburned plots compared to paired plots which burned six to fifteen years previous to the year of study.

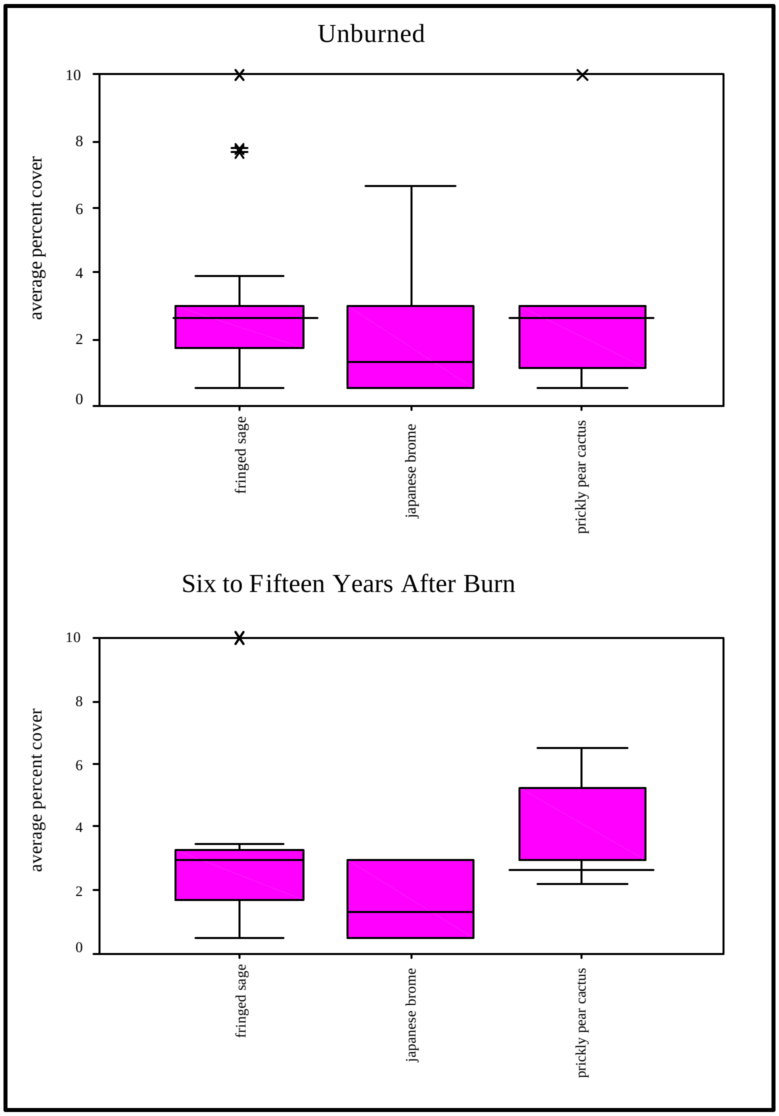


Figure 20. Average canopy cover values of undesirable forage species exhibiting low canopy cover values per transect within unburned plots compared to paired plots that burned six to fifteen years previous to the year of study.

Fringed sage and prickly pear cactus were each found slightly more frequently in unburned transects compared to adjacent burned transects (Table 55). Japanese brome was found in more of the burned transects compared to the unburned transects.

Table 55. Total number of transects ("n" values) in which each species occurred within the unburned grass and shrub type plots and matched plots which burned six to fifteen years prior to the year of study; maximum total occurrences possible (total number of transects studied in each category) is n = 125.

Species	Fringed sage	Japanese brome	Prickly pear cactus
Unburned	45	53	16
Burned	40	58	14

Silver sagebrush, big sagebrush, and greasewood all tend to decrease slightly in cover 6-15 years following fire (Fig. 55). Clubmoss appears to increase in the 6-15 year period following fire.

Silver sagebrush shows similar frequency when comparing burned and unburned sites; clubmoss shows similar frequency as well (Table 56). Big sagebrush was found in 30 percent of the unburned sites compared to only 9 percent of the sites that burned 6-15 years prior. Greasewood was present in fewer unburned sites compared to adjacent burned sites (2 and 6 percent respectively).

Table 56. Total number of transects ("n" values) in which each species occurred within the unburned grass and shrub type plots and matched plots which burned six to fifteen years prior to the year of study; maximum total occurrences possible (total number of transects studied in each category) is n = 125.

Species	Silver sagebrush	Big sagebrush	Greasewood	Clubmoss
Unburned	24	37	3	24
Burned	22	11	7	21

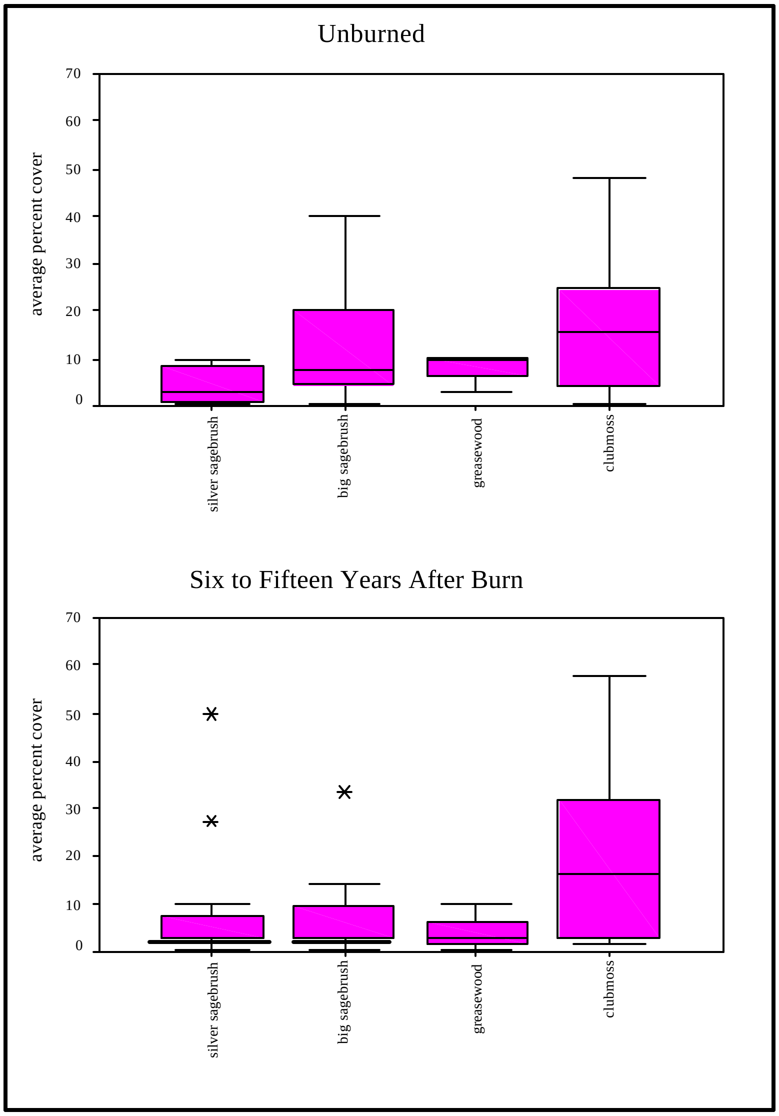


Figure 21. Average canopy cover values of undesirable plant species exhibiting high canopy cover values per transect within unburned plots compared to paired plots that burned six to fifteen years previous to the year of study

Average Cover Values for Transects of Burns more than Fifteen Years of Age and Paired Unburned Plots

Each of the desirable range forage species (excluding crested wheatgrass, which was not present in either the burned or unburned transects in this category) show a slight to noticeable increase in average cover values after 15 years following fire (Fig. 22).

Western wheatgrass, bluebunch wheatgrass, and Sandberg bluegrass were all found in nearly equal frequency between burned and unburned sites (Table 57). Western wheatgrass was present in 80 percent of both categories of transects, whereas Sandberg bluegrass was present in about 30 percent of the transects, and bluebunch wheatgrass was found in 13-18 percent of the transects. Blue grama and green needlegrass were each found in fewer unburned transects compared to matched burned transects (22 to 87 percent and 11 to 36 percent respectively). Prairie Junegrass was present in more unburned transects (58 percent) compared to matched burned sites (42 percent).

Table 57**.** Total number of transects (“n” values) in which each species occurred within the unburned grass and shrub type plots and matched plots which burned over fifteen years prior to the year of study; maximum total occurrences possible (total number of transects studied in each category) is n = 45.

Species	Western wheatgrass	Bluebunch wheatgrass	Blue grama	Prairie Junegrass	Sandberg bluegrass	Green needlegrass	Crested Wheatgrass
Unburned	36	8	10	26	14	5	0
Burned	36	6	39	19	13	16	0

Fringed sage shows an increase in cover in the 15+ year period following fire. Japanese brome shows no change in average cover value comparing unburned sites to those that burned 15+ years prior (Fig. 57). Prickly pear cactus appears to decrease in cover in the 15+ year period following fire.

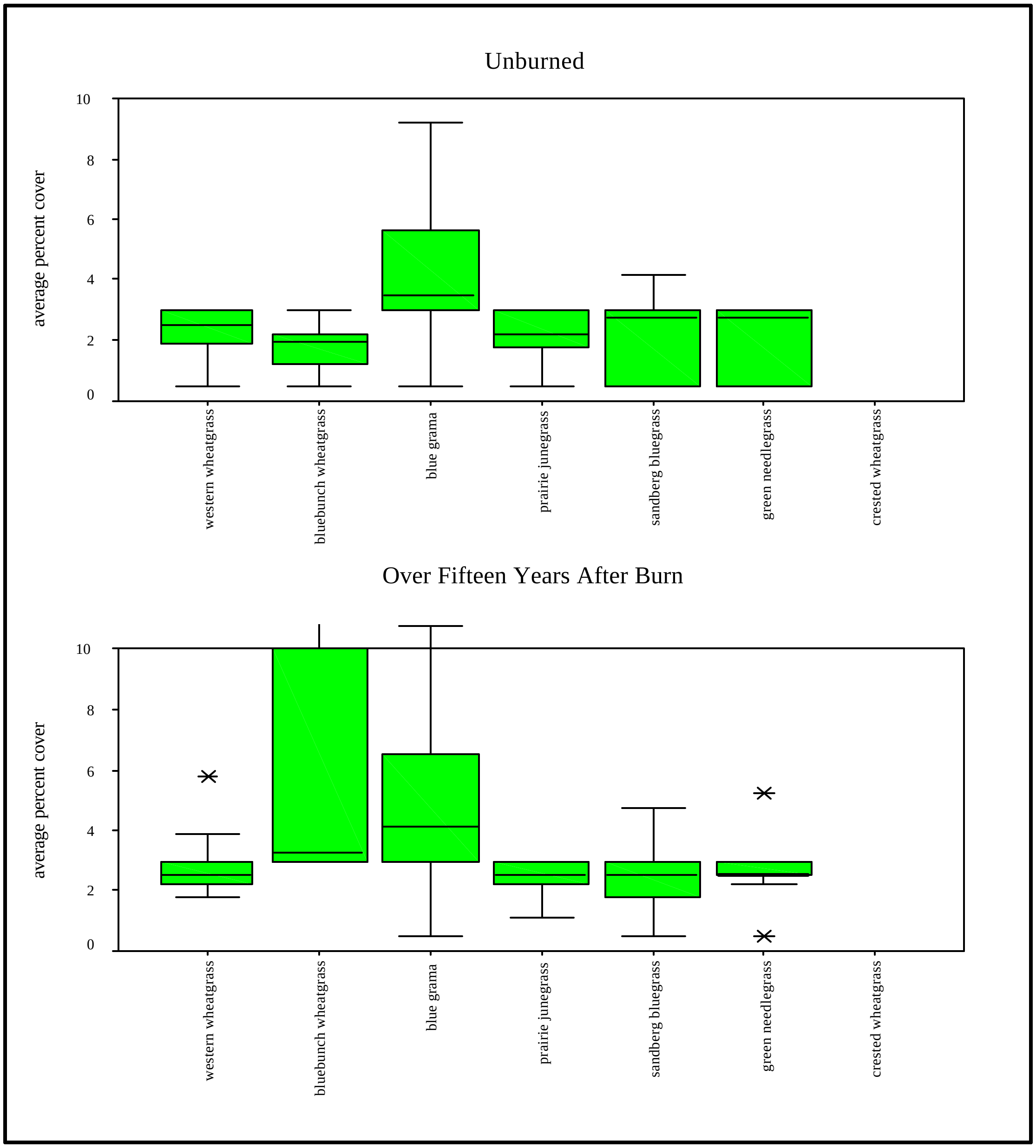


Figure 22**.** Average canopy cover values of desirable forage species per transect within unburned plots compared to paired plots that burned over fifteen years previous to the year of study

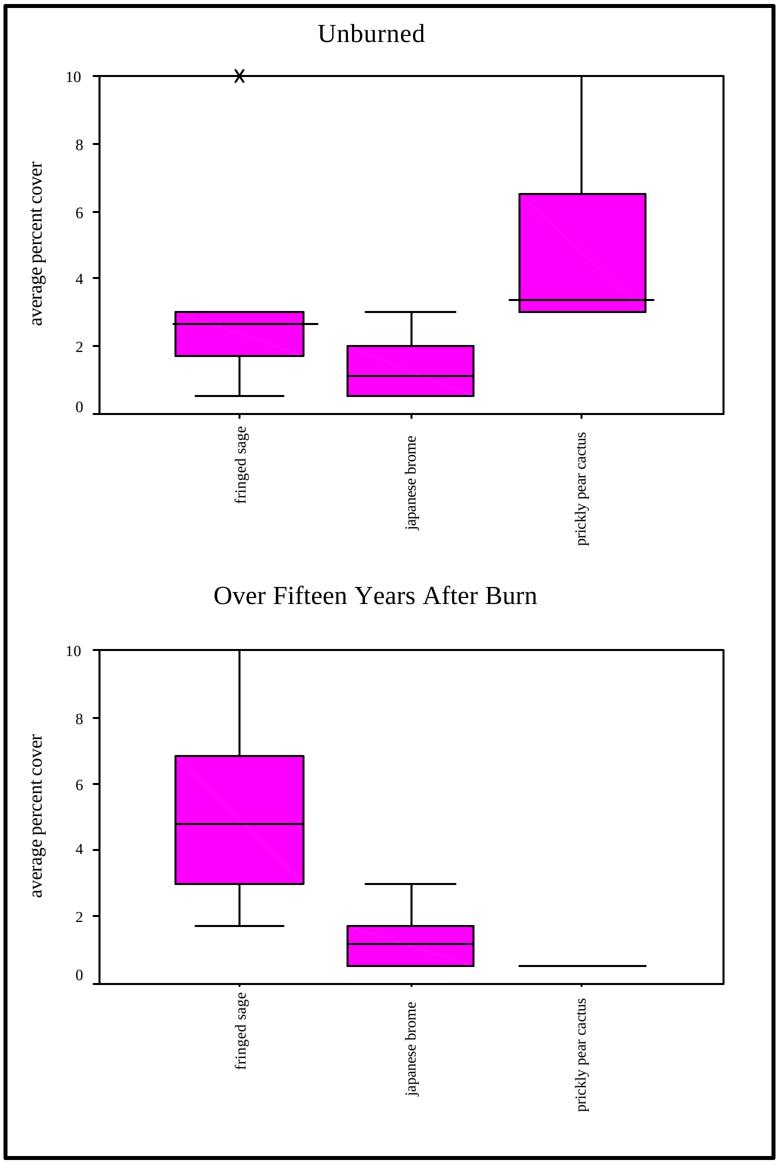


Figure 23. Average canopy cover values of undesirable plant species exhibiting low canopy cover values per transect within unburned plots compared to paired plots that burned more than fifteen years prior to the year of study

Forty-five transects were studied in both unburned areas and adjacent 15+ year old burns (Table 58). Fringed sage was found in 51 percent of the unburned sites compared to 42 percent of the burned sites. Japanese brome was present in 29 percent of the unburned sites compared to 38 percent of the burned matches. Prickly pear cactus was found in only 9 percent of the unburned sites and in fewer still (2 percent) of the burned sites.

Table 58. Total number of transects ("n" values) in which each species occurred within the unburned grass and shrub type plots and matched plots which burned over fifteen years prior to the year of study; maximum total occurrences possible (total number of transects studied in each category) is n = 45.

Species	Fringed sage	Japanese brome	Prickly pear cactus
Unburned	23	13	4
Burned	19	17	1

Silver sagebrush, big sagebrush, and clubmoss all show a decrease in average percent cover in the 15+ year period following fire (Fig. 58). Lack of data for greasewood does not allow a comparison for this species.

Silver sage was found in almost the exact number of unburned transects as matched burned transects (27 and 29 percent respectively) (Table 59). Clubmoss also shows similar frequency values between unburned and burned transects (56 and 51 percent respectively). Big sage was found in one third of the evaluated unburned transects, but in none of the burned matches. Greasewood was not present in any of the evaluated transects in this category.

Table 59. Total number of transects ("n" values) in which each species occurred within the unburned grass and shrub type plots and matched plots which burned over fifteen years prior to the year of study; maximum total occurrences possible (total number of transects studied in each category) is n = 45.

Species	Silver sagebrush	Big sagebrush	Greasewood	Clubmoss
Unburned	12	15	0	25
Burned	13	0	0	23

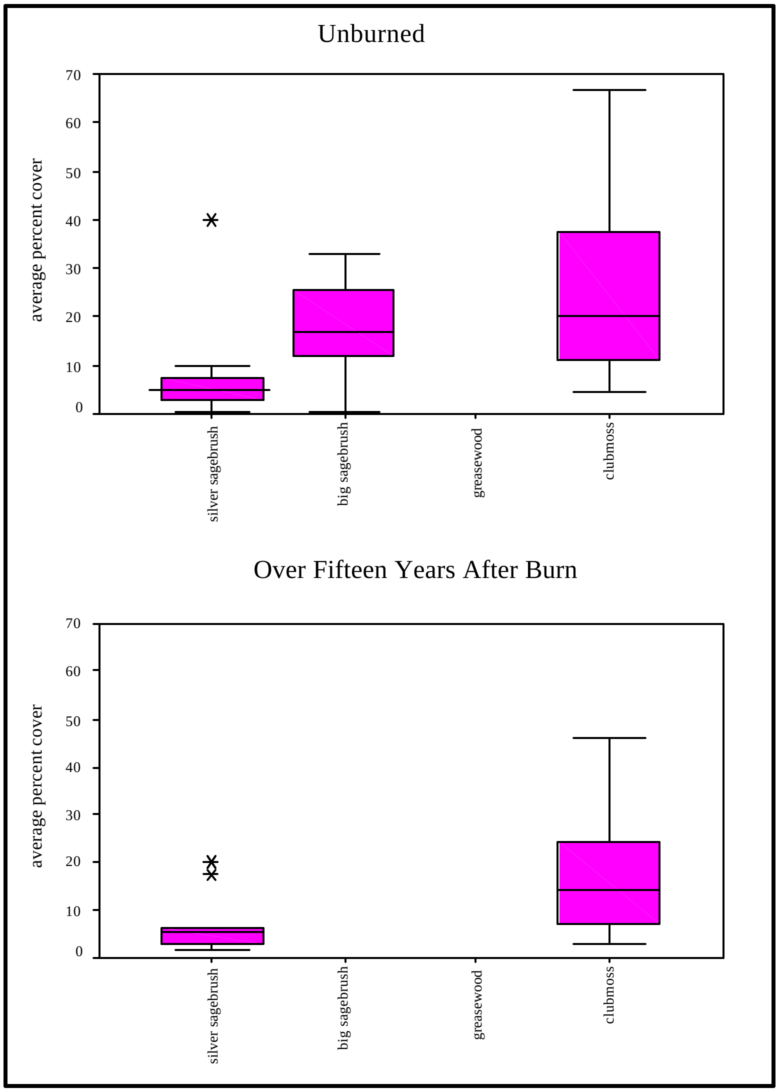


Figure 24. Average canopy cover values of undesirable plant species exhibiting high canopy cover values per transect within unburned plots compared to paired plots that burned more than fifteen years prior to the year of study

Burned vs. Unburned Sites - Testing Significance of Differences in Species Cover Values

Testing Hypothesis for Objective 1

H_1: There is a significant difference in average cover values of individual plant species between an area burned by wildfire and an adjacent unburned area.

"N" values in the following tables represent the number of paired transects compared between unburned and burned areas for each species. Mean differences with positive values signify that the species had higher cover values in the unburned plots compared to the matched burned plots. Mean differences with negative values signify that the species had higher cover values in the burned plots compared to the unburned matches.

Standard deviations of lesser values indicate that the observed values fall into a smaller range; thus, differences are more likely due to an outside factor i.e. fire. Standard deviations of higher values depict a wider range of average cover values, making it more difficult to isolate fire as the causing factor of difference in cover values if a significant difference between burned and unburned plots was indeed discovered. However, large standard deviations are often due to the fact that the particular species was present in smaller amounts in some plots, but was found in extremely high cover values in others.

When comparing all of the unburned plots to all of the burned plots (Table 60), those species that have a test value equal to or less than (p =.05) show a significant difference in average cover values between burned and unburned plots. The species that display significant change are big sagebrush and clubmoss. Additionally, both blue grama and green needlegrass harbor values near the significant level. Big sagebrush and clubmoss each have a positive mean difference value; the statistical test thus shows that these species were found in significantly greater amounts in the unburned plots compared to the burned matches. Blue grama and green needlegrass each have a negative mean difference value; the statistical test shows that these species were found in significantly lesser amounts in the unburned plots compared to the burned matches.

Table 61 shows “N” values for each species in one-year-old burns and paired unburned sites. Those species that display a significant change in cover values one year after a fire are big sagebrush, prickly pear cactus, clubmoss, and blue grama. Big sagebrush and cactus each have a positive mean difference value; the statistical test thus shows that these species were found in significantly greater amounts in the unburned plots compared to the burned matches. Clubmoss and blue grama each have a negative mean value; thus the statistical test shows that these two species were found in a significantly lesser amount in the unburned plots compared to the burned matches.

Table 62 shows “N” values for each species in 2-5 year-old burns and paired unburned sites. Those species that display a significant change in cover values 2-5 years after a fire are western wheatgrass, prairie Junegrass, Sandberg bluegrass, big sagebrush, Japanese brome, and clubmoss. Big sagebrush, Japanese brome, and clubmoss each have a mean difference value that is positive; the statistical test thus shows that these species were present in the unburned plots in a significantly greater amount compared to the burned matched plots. Western wheatgrass, prairie Junegrass, and sandberg bluegrass each have a negative mean difference value; the statistical test thus shows that these species were found in significantly greater amounts in the burned plots compared to the unburned matches. The high standard deviation values for big sagebrush and clubmoss in this study are a result of plots containing very little big sage and clubmoss as well as plots containing high cover of these species.

Table 60. One-Sample Statistics and Significance Test: Unburned vs. Burned

Species	N	Mean Difference	Std. Deviation	Test Value = 0 Sig. (2-tailed)
western wheatgrass	294	-0.0168	+/- 2.8103	0.918
bluebunch wheatgrass	120	0.0480	+/- 4.3456	0.904
blue grama	255	-0.3590	+/- 3.2667	0.080
prairie junegrass	270	-0.0930	+/- 1.6903	0.367
sandberg bluegrass	170	-0.0390	+/- 1.5878	0.749
green needlegrass	175	-0.3077	+/- 2.3363	0.083
crested wheatgrass	35	-0.1477	+/- 2.2791	0.704
silver sagebrush	100	1.0384	+/- 11.2823	0.360
fringed sage	216	-0.2754	+/- 3.2894	0.220
big sagebrush	130	10.2231	+/- 13.1222	0.000
Japanese brome	220	0.1029	+/- 1.5145	0.315
prickly pear cactus	100	0.4192	+/- 3.1109	0.181
greasewood	25	1.8500	+/- 8.1240	0.266
clubmoss	115	7.9756	+/- 17.2702	0.000

Table 61. One-Sample Statistics and Significance Test: 1Year Old Burns vs. Unburned Matches

Species	N	Mean	Std. Deviation	Test Value = 0 Sig. (2-tailed)
western wheatgrass	25	-0.0880	+/- 1.5501	0.779
bluebunch wheatgrass	5	0.3500	+/- 1.5772	0.646
blue grama	20	-2.1985	+/- 5.0657	0.067
prairie junegrass	25	-0.4220	+/- 1.6397	0.210
sandberg bluegrass	15	0.3067	+/- 1.6586	0.486
green needlegrass	15	-0.3500	+/- 1.3621	0.337
crested wheatgrass	0	*	*	*
silver sagebrush	5	2.0000	+/- 4.4721	0.374
fringed sage	15	0.0000	+/- 0.2673	1.000
big sagebrush	10	5.9300	+/- 5.9135	0.011
Japanese brome	25	-0.0400	+/- 0.7169	0.783
prickly pear cactus	10	1.2920	+/- 1.9553	0.066
greasewood	0	*	*	*
clubmoss	10	-10.5850	+/- 17.2331	0.084

* cannot be computed because the sample size is too small

Table 63 shows “N” values for each species in 6-15 year-old burns and paired unburned sites. Those species that display a significant change in cover values 6-15 years after a fire are blue grama, sandberg bluegrass, and big sagebrush. Big sagebrush and sandberg bluegrass each hold positive mean difference values; thus the statistical test reveals that these species were present in significantly higher amounts in the unburned plots compared to the burned matched plots. Blue grama exhibits a negative mean difference value; thus the statistical test states that blue grama was present in a significantly greater amount in the burned plots compared to the unburned matches. Silver sagebrush, big sagebrush, greasewood, and clubmoss all illustrate high standard deviation values due to their scarce presence on some plots and their very high canopy cover values in others.

Table 64 shows “N” values for each species in burns greater than 15 years old and paired unburned sites. Those species that display a significant change in cover values more than 15 years after a fire are green needlegrass, fringed sage, big sagebrush, and clubmoss. Big sagebrush and clubmoss each harbor positive mean difference values; the significance test thus reveals that these species were found in significantly greater amounts in the unburned plots compared to the burned matches. Green needlegrass and fringed sage display negative mean difference values; the significance test thus shows that these two species were present in significantly greater amounts in the burned plots compared to the unburned matches. Big sagebrush and clubmoss show high standard deviation values due to their varied presence in plots – extremely high coverage in some plots, and complete absence in other plots.

Table 62**.** One-Sample Statistics and Significance Test: 2-5 Year Old Burns vs. Unburned Matches

Species	N	Mean Difference	Std. Deviation	Test Value = 0 Sig. (2-tailed)
western wheatgrass	104	-0.4092	+/- 1.8986	0.030
bluebunch wheatgrass	50	-0.4960	+/- 2.6254	0.188
blue grama	90	0.0141	+/- 1.8077	0.941
prairie junegrass	100	-0.4593	+/- 1.8102	0.013
sandberg bluegrass	65	-0.5566	+/- 1.6512	0.008
green needlegrass	60	0.1213	+/- 1.9609	0.634
crested wheatgrass	20	-0.2125	+/- 2.7261	0.731
silver sagebrush	40	0.3980	+/- 8.9132	0.779
fringed sage	86	-0.1342	+/- 3.1412	0.693
big sagebrush	45	10.4589	+/- 14.2839	0.000
Japanese brome	70	0.5271	+/- 1.1048	0.000
prickly pear cactus	45	0.3667	+/- 2.2699	0.284
greasewood	5	1.0000	+/- 2.2361	0.374
clubmoss	40	15.6543	+/- 16.0824	0.000

Table 63. One-Sample Statistics and Significance Test: 6-15 Year Old Burns vs. Unburned Matches

Species	N	Mean Difference	Std. Deviation	Test Value = 0 Sig. (2-tailed)
western wheatgrass	120	0.4288	+/- 3.7714	0.215
bluebunch wheatgrass	50	1.1320	+/- 5.1336	0.125
blue grama	100	-0.5031	+/- 3.0181	0.099
prairie junegrass	100	0.2537	+/- 1.5307	0.101
sandberg bluegrass	70	0.4807	+/- 1.2606	0.002
green needlegrass	75	-0.2861	+/- 2.8283	0.384
crested wheatgrass	15	-0.0613	+/- 1.5860	0.883
silver sagebrush	35	2.4977	+/- 15.4239	0.345
fringed sage	80	-0.0808	+/- 3.6698	0.844
big sagebrush	60	9.0548	+/- 13.3120	0.000
Japanese brome	90	-0.1627	+/- 1.9558	0.432
prickly pear cactus	35	-0.1714	+/- 4.0711	0.805
greasewood	20	2.0625	+/- 9.0597	0.321
clubmoss	40	1.2665	+/- 14.7734	0.591

Table 64**.** One-Sample Statistics and Significance Test: 15+ Year Old Burns vs. Unburned Matches

Species	N	Mean Difference	Std. Deviation	Test Value = 0 Sig. (2-tailed)
western wheatgrass	45	-0.2589	+/- 1.8460	0.352
bluebunch wheatgrass	15	-1.8520	+/- 5.8555	0.241
blue grama	45	0.0324	+/- 4.6249	0.963
prairie junegrass	45	0.1333	+/- 1.6321	0.586
sandberg bluegrass	20	-0.4350	+/- 1.8085	0.296
green needlegrass	25	-1.3768	+/- 1.6490	0.000
crested wheatgrass	0	*	*	*
silver sagebrush	20	-0.4750	+/- 7.9257	0.792
fringed sage	35	-1.1851	+/- 3.3774	0.046
big sagebrush	15	17.0507	+/- 10.3422	0.000
Japanese brome	35	0.0391	+/- 1.1598	0.843
prickly pear cactus	10	1.8500	+/- 3.2150	0.102
greasewood	0	*	*	*
clubmoss	30	7.8260	+/- 19.3526	0.035

* values cannot be computed because the sample size is too small

Successional Change -- Testing Significance of Differences in Species Cover Values in Years Following Fire:

Testing Hypothesis for Objective 2

H_1: There is a significant difference in average cover values of individual plant species between burned sites of different age classes.

Species showing a significant difference in average cover values between the successional stages following fire depict a test value of ($p < .05$); values slightly above the standard p-value (.08, .09) are also considered significant. Comparisons are shown in Table 65.

Table 65. Significance tests for canopy cover value differences between successional stages following fire

t-test for equality of means Sig. (2-tailed)				
	Unburned vs. 1-year burns	1-year burns vs. 2-5 year burns	2-5 year burns vs. 6-15 year burns	6-15 year burns vs. 15+ year burns
Species				
western wheatgrass	0.907	0.826	0.374	0.531
bluebunch wheatgrass	0.965	0.923	0.844	0.208
blue grama	0.258	0.150	0.004	0.092
prairie junegrass	0.960	0.774	0.892	0.791
sandberg bluegrass	0.264	0.054	0.584	0.008
green needlegrass	0.412	0.457	0.273	0.552
crested wheatgrass	0.928	0.760	0.135	*
silver sagebrush	*	*	0.942	0.873
fringed sage	0.336	0.221	0.835	0.028
big sagebrush	*	*	0.080	*
Japanese brome	0.129	0.127	0.014	0.063
prickly pear cactus	0.462	*	0.692	0.094
greasewood	*	*	0.591	*
Clubmoss	0.289	0.082	0.686	0.717

* cannot be calculated because species has too small a sample size

Comparing species cover between unburned areas and areas that burned one year prior illustrates no significant difference between cover values for any of the species tested. However, the sample size for most of the species occurring in areas that burned one year prior is too small for accurate testing.

Species that show a significant difference in cover values between one-year-old burns and 2-5 year old burns are Sandberg bluegrass and clubmoss. Sandberg bluegrass has a higher average percent cover in sites that burned one year ago compared to sites that burned 2-5 years ago. Clubmoss also has a higher average percent cover in sites that burned one year ago compared to sites that burned 2-5 years ago. However, the sample size for clubmoss in both burn ages is too small to deduce a conclusion.

Species in the comparison category of 2-5 year old burns and 6-15 year old burns showing a significant difference in average cover values are: blue grama, big sagebrush, and Japanese brome. Blue grama harbored higher cover values in areas that burned 6-15 years prior compared to areas that burned 2-5 years prior. Japanese brome was present in greater amount in areas that burned 6-5 years ago compared to areas that had burned 2-5 years prior. Big sagebrush, (p-value of .08) shows a significant difference as well. Comparing the three transects harboring sagebrush in the 2-5 year old age class with the eleven transects containing big sagebrush in the 6-15 year age class illustrates that big sage was present in higher cover in the area that burned 2-5 years prior. However, the sample size of transects containing big sagebrush in areas that burned 2-5 years previously is not large enough to draw any solutions through this comparison.

Species showing a significant difference in average cover values between burns 6-15 years old and 15+ year-old burns are: blue grama, sandberg bluegrass, fringed sage, Japanese brome, and prickly pear cactus. Blue grama, sandberg bluegrass, and fringed sage were all found in greater amounts in areas that had burned 15+ years prior compared to areas that had burned 6-15 years prior. Japanese brome held higher cover values in areas that burned 6-15 years ago compared to areas that burned 15+ years ago. There was only one transect in the 15+ age class burns where prickly pear cactus was present, so although it appears to have higher cover values in the 6-15 year age class compared to the 15+ age class, the sample size is to small to draw a sound conclusion.

Significance tests for these species may not accurately represent their response to fire, as many of the sample sizes are too small. Tables 66-69 below show frequency values (n-values) for each species in each category. Those species with high frequency in each of the compared categories display more accuracy in the significance tests than those species with a low n-value.

"N" values represent the number of transects in which each species occurred within each of the burn categories (unburned plots and plots that burned one year prior). The mean value shows that average canopy cover value for each species within each burn type. Standard deviation values illustrate the spread above and below the mean in which 68 percent of the all of the values fall.

Table 66. Group Statistics – Unburned Plots vs. 1 Year Old Burns

Species		N	Mean	Std. Deviation
western wheatgrass	0	232	2.87	+/- 4.39
	1	20	2.76	+/- 1.58
bluebunch wheatgrasss	0	76	2.82	+/- 4.00
	1	1	3.00	*
blue grama	0	168	3.27	+/- 2.55
	1	11	5.25	+/- 5.45
prairie junegrass	0	168	2.65	+/- 2.74
	1	17	2.62	+/- 1.02
sandberg bluegrass	0	92	2.33	+/- 1.32
	1	7	2.64	+/- 0.61
green needlegrass	0	70	2.51	+/- 2.03
	1	5	1.75	+/- 1.25
crested wheatgrass	0	10	2.84	+/- 1.63
	1	1	3.00	*
silver sagebrush	0	49	7.24	+/- 9.03
	1	0	*	*
fringed sagebrush	0	114	3.17	+/- 2.74
	1	8	2.22	+/- 1.15
big sagebrush	0	107	12.44	+/- 12.65
	1	0	*	*
Japanese brome	0	143	2.00	+/- 3.23
	1	14	0.68	+/- 0.67
prickly pear cactus	0	36	3.64	+/- 3.53
	1	2	1.75	+/- 1.77
greasewood	0	14	11.29	+/- 9.11
	1	0	*	*
clubmoss	0	91	21.79	+/- 17.21
	1	7	29.14	+/- 22.36

{0} = Unburned plots
{1} = Plots that burned 1 Year Ago
* cannot be computed because the species has too small a sample size

Table 67. Group Statistics – 1 Year Old Burns vs. 2-5 Year Old Burns

Species		N	Mean	Std. Deviation
western wheatgrass	1	20	2.76	+/- 1.58
	2-5	74	2.86	+/- 1.98
bluebunch wheatgrass	1	1	3.00	*
	2-5	30	2.76	+/- 2.44
blue grama	1	11	5.25	+/- 5.45
	2-5	62	2.69	+/- 1.33
prairie junegrass	1	17	2.62	+/- 1.02
	2-5	59	2.52	+/- 1.35
sandberg bluegrass	1	7	2.64	+/- 0.61
	2-5	38	1.88	+/- 1.85
green needlegrass	1	5	1.75	+/- 1.25
	2-5	26	2.50	+/- 2.14
crested wheatgrass	1	1	3.00	*
	2-5	9	2.91	+/- 0.28
silver sagebrush	1	0	*	*
	2-5	11	7.36	+/- 6.59
fringed sage	1	8	2.22	+/- 1.15
	2-5	34	3.82	+/- 3.56
big sagebrush	1	0	*	*
	2-5	3	21.00	+/- 15.59
Japanese brome	1	14	0.68	+/- 0.67
	2-5	21	1.08	+/- 0.78
prickly pear cactus	1	2	1.75	+/- 1.77
	2-5	0	*	*
greasewood	1	0	*	*
	2-5	0	*	*
clubmoss	1	7	29.14	+/- 22.36
	2-5	5	10.92	+/- 7.80

{1} = Plots that burned 1 year ago
{2-5} = Plots that burned 2-5 years ago
* cannot be computed because the species has too small a sample size

Table 68. Group Statistics – 2-5 Year Old Burns vs. 6-15 Year Old Burns

		N	Mean	Std. Deviation
western wheatgrass	2-5	74	2.86	+/- 1.98
	6-15	89	2.57	+/- 2.19
bluebunch wheatgrass	2-5	30	2.76	+/- 2.44
	6-15	26	2.88	+/- 1.98
blue grama	2-5	62	2.69	+/- 1.33
	6-15	51	3.97	+/- 2.80
prairie junegrass	2-5	59	2.52	+/- 1.35
	6-15	65	2.49	+/- 1.33
sandberg bluegrass	2-5	38	1.88	+/- 1.85
	6-15	47	2.06	+/- 0.86
green needlegrass	2-5	26	2.50	+/- 2.14
	6-15	35	3.10	+/- 2.07
crested wheatgrass	2-5	9	2.91	+/- 0.28
	6-15	4	1.85	+/- 1.04
silver sagebrush	2-5	11	7.36	+/- 6.59
	6-15	22	7.09	+/- 11.15
fringed sage	2-5	34	3.82	+/- 3.56
	6-15	40	3.66	+/- 2.86
big sagebrush	2-5	3	21.00	+/- 15.59
	6-15	11	7.50	+/- 9.60
Japanese brome	2-5	30	1.14	+/- 0.85
	6-15	58	1.86	+/- 1.85
prickly pear cactus	2-5	6	3.58	+/- 1.43
	6-15	14	3.92	+/- 1.83
greasewood	2-5	1	10.00	*
	6-15	7	5.71	+/- 7.06
clubmoss	2-5	14	15.85	+/- 11.98
	6-15	21	17.97	+/- 16.80

{2-5} = Plots that burned 2-5 years ago
{6-15} = Plots that burned 6-15 years ago
* cannot be computed because the species has too small a sample size

Table 69. Group Statistics – Burned 6-15 Years Ago vs. Burned 15+ Years Ago

Species		N	Mean	Std. Deviation
western wheatgrass	6-15	89	2.57	+/- 2.19
	15+	36	2.75	+/- 1.00
bluebunch wheatgrass	6-15	26	2.88	+/- 1.98
	15+	6	7.00	+/- 6.96
blue grama	6-15	51	3.97	+/- 2.80
	15+	39	5.04	+/- 3.16
prairie junegrass	6-15	65	2.49	+/- 1.33
	15+	19	2.55	+/- 0.77
sandberg bluegrass	6-15	47	2.06	+/- 0.86
	15+	13	2.93	+/- 1.42
green needlegrass	6-15	35	3.10	+/- 2.07
	15+	16	2.78	+/- 0.98
crested wheatgrass	6-15	4	1.85	+/- 1.04
	15+	0	*	*
silver sagebrush	6-15	22	7.09	+/- 11.15
	15+	13	7.65	+/- 6.77
fringed sage	6-15	40	3.66	+/- 2.86
	15+	19	5.40	+/- 2.62
big sagebrush	6-15	11	7.50	+/- 9.60
	15+	0	*	*
Japanese brome	6-15	58	1.86	+/- 1.85
	15+	17	1.27	+/- 0.80
prickly pear cactus	6-15	14	3.92	+/- 1.83
	15+	1	0.50	*
greasewood	6-15	7	5.71	+/- 7.06
	15+	0	*	*
clubmoss	6-15	21	17.97	+/- 16.80
	15+	23	16.35	+/- 12.53

{6-15} = Plots that burned 6-15 years ago
{15+} = Plots that burned more than fifteen years ago
* cannot be computed because the species has too small a sample size

Discussion

This study shows that different plant species respond by either increasing in cover, decreasing in cover, or maintaining constant average cover values in response to fire.

There is not enough data to determine a difference in cover values between the unburned plots and the first year following a fire for the following species: bluebunch wheatgrass, blue grama, Sandberg bluegrass, green needlegrass, crested wheatgrass, silver sagebrush, fringed sage, big sagebrush, Japanese brome, prickly pear cactus, greasewood, or clubmoss. This is due to the extremely small sample size for these species in the one year old burn category.

The reader is encouraged to visit the USDA Forest Service Fire Effects Information System web site at www.fs.fed.us/database/feis for a comprehensive literature review of fire effects on individual plant species.

Western Wheatgrass

In comparing just the one year old burns to their adjacent unburned matches, there is no significant difference in western wheatgrass cover values between burned and unburned sites. When comparing the 2-5 year old burns with their unburned matches western wheatgrass is found in significantly higher amounts in the burned plots compared to the unburned matches. When comparing the 6-15+ year old burns with their unburned matches no significant difference in western wheatgrass cover values is apparent.

Western wheatgrass displays a slight increase in cover values in the years following the second year after a fire. However, burns dated as 6 years old and beyond do not show a significant difference in cover when compared to adjacent unburned areas.

Evidence supports that western wheatgrass is generally unharmed by fire. Additional studies (Dittberner and Olson 1983, Bone and Klukas 1990, Gartner 1975) found that burning in spring, fall, and winter enhanced production of western wheatgrass.

Western wheatgrass shows no significant difference in cover values between the successional age classes of burns. Fire does not appear to harm western wheatgrass. On some sites western wheatgrass even increased after a burn. Therefore, fire can be used in managing rangelands without sacrificing western wheatgrass cover, and may possibly even promote growth.

Bluebunch Wheatgrass

A comparison of the one year old burns to adjacent unburned sites illustrates no significant difference in bluebunch wheatgrass cover between the two types. However, the sample size for this age class is too small to make inferences on the immediate response of bluebunch wheatgrass to fire. Following fire, bluebunch wheatgrass shows no significant change in cover values in any of the age classes of burns compared to unburned areas.

My study showed that fire in the Northern Mixed Grass Prairie does not cause a change in cover values of bluebunch wheatgrass. Other studies show a varied response of bluebunch wheatgrass to fire. McShane and Sauer (1985) found that burning bluebunch wheatgrass when the plants are dormant causes no harm, whereas actively growing plants may decrease in production following fire. Agee (1996) found that fire stimulates flowering and seed production, thus promoting growth. Furthermore, Thompson (1990) noted an initial reduction in growth the first year after fire, followed by an increased level of productivity in subsequent years.

There is not sufficient data available from this study to determine the difference in cover values of bluebunch wheatgrass between the one year and 2-5 year age classes and the 6-15 year to 15+ year age classes. However, bluebunch wheatgrass does not show a significant change in cover between the 2-5 year burns and the 6-15 year burns.

Blue Grama

When comparing areas that burned one year prior with adjacent unburned areas, blue grama is found in significantly greater amounts in the burned areas. Looking at the 2-5 year old burns and comparing them to adjacent unburned areas illustrates no significant difference in blue grama cover between the two. However, when focusing on areas that burned 6-15 years prior, and comparing these to adjacent unburned areas, blue grama is present in a significantly higher amount in the burned areas. When looking at 15+ year old burns, no difference in blue grama cover values is found between these burns and adjacent unburned sites.

Data shows that blue grama's immediate response to fire is an increase in production. In the following years the comparison between burned and unburned plots illustrates no difference in cover values in the 2-5 year period following fire and a significant increase in blue grama in the 6-15 year period following a fire. In general it appears that fire causes an increase in blue grama cover. Literature suggests that the response of blue grama to fire is determined mainly by the season of burn. White and Currie (1983) found that burning when blue grama is dormant causes minimal harm to the plant, but that spring fires cause a reduction in plant yield. However, plants usually recover within the same year or subsequent years thereafter.

Blue grama shows an increase in cover values in the 6-15 year period following a fire as well as an increase in the 15+ years following fire.

Prairie Junegrass

Prairie Junegrass depicts no change in cover the year immediately following a fire. When comparing the 2-5 year old burns to adjacent unburned areas, prairie Junegrass is present in significantly greater amounts in the burned areas. In subsequent years there is no significant difference between burned areas and adjacent unburned areas.

Fire allows prairie Junegrass to increase in cover in the second year following the burn. This supports Blaisdell's (1953) findings. However, in the 5-15+ year period following a fire, there is no significant difference in cover values between burned and unburned areas. Aldous (1934) found a similar response where prairie Junegrass increased production for up to five years following fire, and then no difference in production was apparent.

Prairie Junegrass shows no significant change in cover between successional age classes of burns.

Sandberg Bluegrass

Sandberg bluegrass shows no change in cover values the year immediately following a fire. Comparing the 2-5 year old burns to adjacent unburned areas illustrates that sandberg bluegrass is found in significantly higher amounts in the burned sites. In the 6-15 year old burns sandberg bluegrass is found in significantly lower amounts than in comparative adjacent unburned areas. In areas that burned over fifteen years ago there is no significant difference between sandberg bluegrass cover when compared to adjacent unburned sites.

Wright and Klemmedson (1965) found Sandberg bluegrass production to increase in immediate years following fire, due to a reduction in competition with fire-susceptible big sagebrush. Pechanec et al. (1965) found varied responses in production following fire, but maintained that Sandberg bluegrass is generally unharmed by fire.

Green Needlegrass

In general, fire does not cause a significant change in cover values of green needlegrass. However, the oldest burns studied show a significant amount more green needlegrass when compared to adjacent unburned plots. As there was no initial increase in green needlegrass following the burns, fire may not be the factor responsible for causing an increase in cover for this species 15 years after the burn. One explanation is a possible discrepancy in matched site selection. Or perhaps, fire allows for an initial increase in those grass species that compete directly with green needlegrass, and in the late successional stages when production of these grasses levels off, green needlegrass has a chance to increase plant production.

Other studies (Engle and Bultsma 1984, Whisenant and Uresk 1990) found that fire effects vary with season of burn and severity of fire. Whisenant and Uresk (1990) noted a significant decrease in green needlegrass for three seasons following a prescribed burn in the spring. Engle and Bultsma (1984) studied a June burn on a Northern Mixed Grass Prairie site, and found that green needlegrass returned to normal production levels the year following fire.

Crested Wheatgrass

Crested wheatgrass was not present in any of the studied plots that burned one year prior, so no conclusions about the immediate effects of fire on this species can be drawn. Crested wheatgrass shows no significant difference in cover between unburned areas and burned areas of ages 2-15 years following a fire. No plots in the 15+ year age class matches contained crested wheatgrass, so no conclusions could be drawn from that age class.

Pechanec et al. (1954) determined that crested wheatgrass generally remains unharmed by fire. However, Bradley et al. (1992) found fall burns to reinvigorate crested wheatgrass stands, while spring fires decreased yields for several years.

Silver Sagebrush

Silver sagebrush was present in only one plot that burned the previous year. It displays no difference between the burned and unburned site, but the sample size for one year old burns containing silver sagebrush is too small to draw any sound conclusions.

Silver sagebrush depicts no significant difference in cover values between unburned plots and burned plots of all ages in the years following a fire. Silver sagebrush does not show a significant increase or decrease in percent cover in the years following a fire. The response of silver sagebrush in the first year following fire is inconclusive.

Other studies show that season of burn and intensity of fire play a role in the percent mortality of silver sagebrush caused by fire. As the burn intensity and severity increase, plant mortality increases and regrowth decreases (White and Currie 1983a). Focusing on season of burn and fire intensity, White and Currie (1983b) compared a spring fast-moving headfire to a fall slow-moving backfire and found that fall burning caused a greater reduction in silver sagebrush plants.

Fringed Sage

Fringed sage shows no significant difference in cover between an area that burned the year prior and an adjacent unburned area. Fringed sage shows no significant difference in cover between areas that burned 2-15 years previously and adjacent unburned areas. Comparing areas that burned 15+ years prior to adjacent unburned areas reveals that fringed sage is present in significantly greater amounts in the areas that had burned.

The response of fringed sagebrush to fire has been found to vary with fire intensity. Following low severity fires, fringed sage, a weak sprouter, is able to recover (Cawker 1983). Severe fires seriously damage or kill fringed sage plants (Bailey, A.W. 1978).

Big Sagebrush

Big sagebrush grows in significantly less amounts in areas that burned one year prior compared to adjacent unburned areas. In all plots studied, dating from 2-15+ year old burns, big sagebrush is present in significantly less amounts in burned areas compared to adjacent unburned areas.

Fire causes a significant reduction in big sagebrush cover. Peek et al. (1979) and Eichhorn and Watts (1984) reported that fire reduces big sagebrush on sites for up to thirty years.

Japanese Brome

Japanese brome shows no significant difference in cover between areas that burned one year previously and adjacent unburned areas. Comparing the plots that burned 2-5 years previously to adjacent unburned areas illustrates that Japanese brome is found in significantly greater amounts in the unburned areas. In the higher age class fires there is no significant difference in Japanese brome cover values between burned areas and unburned areas.

Data from this study show that fire may cause a decrease in Japanese brome cover beginning in the second year following the burn. But as time progresses, burned areas and adjacent unburned areas show no significant difference in Japanese brome cover between them. Whisenant (1990) warns that Japanese brome is a prolific seed producer and thus a competitive colonizer on burned sites. Once seeds have been dropped in late summer, a large viable seed source awaits germination, thus giving Japanese brome an advantage over other species. However, Gartner (1975) found that spring fires can be used to reduce the number of plants on a site, and also to reduce the number of viable seeds available for recolonization the following year. Season of burn evidently plays a key role in the response of Japanese brome to fire.

Prickly Pear Cactus

Prickly pear cactus is found in significantly less amounts in areas that had burned one year prior compared to adjacent unburned areas. Comparing burned areas in later successional stages with unburned areas reveals no significant difference in prickly pear cactus cover.

Fire seems to cause an immediate reduction in prickly pear cactus cover, but in subsequent years following fire there appears to be no difference in prickly pear cover between burned and unburned areas.

Humphrey (1974) and Smith et al. (1985) suggest that the response of prickly pear to fire is determined by fire intensity. High intensity fires can greatly reduce the amount of prickly pear on a site, whereas low intensity burns cause little damage to the cactus plants and allow for adventitious root sprouting by the remaining pads. Reynolds and Bohning (1956) noted that fire weakened prickly pear plants, making them susceptible to damage by insects and disease. Furthermore, fire destroys the spines, making the pads available to foraging animals, and thus exerting additional stress on the plants.

Greasewood

Greasewood was not present in any of the one year old burned plots, so no data is available to compare species cover between one year burns and adjacent unburned areas. Greasewood shows no significant difference in cover values between burned and unburned areas in the 2-15 year range following fire. Greasewood was not present in any of the 15+ year old burns, so no data is available to compare cover values between older burns and adjacent unburned areas.

Greasewood grows in dense stands in some river bottom sites, and is also found growing sporadically in upland sites, mainly those featuring saline soils. The greasewood sites included in this study were those upland sites where greasewood was present in thinner amounts. Fire did not cause a significant change in greasewood cover in the sites recorded in this study. However, Daubenmire (1970) argues that black greasewood sprouts vigorously following fire, thus increasing in production and cover. Furthermore, Roundy et al. (1981) found greasewood to increase in both growth rate and seed production following fire. On the other hand, during a fall burn in Wyoming where high fuel loading led to high intensity burning, greasewood plants exhibited a greater mortality than predicted on the basis of the plant's ability to resprout (Smith 1966).

Clubmoss

Clubmoss was present in only two of the one- year-old burn plots studied. It shows a significant difference between these plots and the adjacent unburned plots (occurring in higher amounts in the burned plots compared to the unburned plots), however, the sample size of one year old burn plots containing clubmoss is too small to draw concrete conclusions. Additionally, Rowe (1969) contradicts this evidence, arguing that with sufficient fuels, fire can completely remove clubmoss from a site. The increase in clubmoss production the year immediately following fire could be a result of a small sample size, or possibly the fire lacked sufficient fuel to consume the clubmoss, but reduced the grasses on site, thus allowing clubmoss a competitive advantage. Another possibility is that the burn year was followed by a drought year, thus making it hard for the perennial plants to regain vigor, while simultaneously allowing clubmoss (with its shallow root system) to make use of the light soil moisture.

Comparing the 2-5 year old burns to adjacent unburned areas reveals that clubmoss is present in lesser amounts in the burned areas. In comparing the 15+ year old burns and adjacent unburned plots it is also apparent that clubmoss is present in lesser amounts in these burned areas. Studying 6-15 year old burns and comparing them to unburned areas reveals no difference in cover values for clubmoss. Rowe (1969), Wilson and Shay (1990) and Dix (1960) all found that fire causes a significant reduction in clubmoss production.

Fire can cause a decrease in percent cover of clubmoss in rangelands. However, for a significant reduction in clubmoss to occur, there must be sufficient fuels to carry a fire. Rocky, bare, upland sites containing clubmoss most likely do not have adequate fuel to maintain the fire intensity required to cause a dramatic reduction in clubmoss. Instead of a continuous bed of fuel, these sites harbor patches of grass among bare ground and rocks, which leads to fires displaying a patchy, mosaic pattern of burned grasses intermixed with unburned patches of vegetation. Following fire on these sites, clubmoss did not show a decrease in production in this study.

LITERATURE CITED

Agee, J. K. 1996. Fire in the Blue Mountaina: a history, ecology, and research agenda. In: Jaindl, R. G.; Quigley, T. M., eds. Search for a solution: sustaining the land, people and economy of the Blue Mountains. American Forests:119-145.

Albini, F. A. 1976. Estimating wildfire behavior and effects. USDA For. Serv. Gen. Tech. Rep. INT-30. Intermountain Forest and Range Experiment Station. 92 pp.

Aldous, Q. E. 1934. Effect of burning on Kansas bluestem pastures. Tech. Bul. 38. Manhattan, Kansas: Kansas State College of Agriculture and Applied Science, Agri. Exp. Sta. 65 pp.

Anderson, K.L. 1965. Time burning as it affects soil moisture in upland bluestem prairie in the Flint Hills. Journal of Range Management 18(6): 311-316.

Atwood, W.W. 1940. The Physiographic Provinces of North America. Ginn and Company, Boston.

Bailey, A. W. 1978. Use of fire to manage grasslands of the Great Plains: Northern Great Plains and adjacent forests. In: Hyder, Donald N., ed. Proceedings, 1st International Rangeland Conference: August 14-18, Denver, Colorao. Society for Range Management:691-693.

Bailey, A. F., N. V. Noste and W. C. Fischer. 1992. Fire ecology of forests and woodlands of Utah. Gen. Tech. Rep. INT-287. Ogden, Utah: U. S. Department of Agriculture, Forest Service, Intermountain Research Station. 128 pp.

Barbour, Michael G., Jack H. Burk and Wanna D. Pitts. 1980. Terrestrial plant ecology. Benjamin/Cummings Publ. Co., Inc., Menlo Park, California. 604 pp.

Barker, W. T. and W. C. Whitman. 1988. Vegetation of the northern Great Plains. Rangelands 10:266-272.

Barrett, S. W. 1980. Indians and fire. Western Wildlands 6(3):17-21.

Biondini, M. E., A. A. Steuter and R. G. Hamilton. 1999. Bison use of fire-managed remnant prairies. *Journal of Range Management* 52:454-461.

Biswell, H. H. 1972. Fire ecology in ponderosa-pine grassland. Proc. Tall Timbers Fire Ecol. Conf. 12:69-96.

Blaisdale, J. P. 1953. Ecological effects of planned burning of sagebrush-grass range on the upper Snake River Plains. USDA For. Serv. Tech. Bull. 1075. 39 pp.

Bone, S. D. and R. W. Klukas. 1990. Prescribed fire in Wind Cave National Park. In: Alexander, M. E. and G. F. Bisgrove, technical coordinators. The art and science of fire management: Proceedings, 1st Interior West Fire Council annual meeting and workshop; 1988 October 24-27: Kananaskis Village, Alberta. Inf. Rep. NOR-X-309. Edmonton, Alberta: Forestry Canada, Northwest Region, Northern Forestry Centre:297-302.

Bonham, C. D. and A. Lerwick. 1976. Vegetation changes induced by prairie dogs on shortgrass range. J. Range Manage. 29:221-225.

Borchert, J.R. 1971. The dust bowl in the 1970's. Annals of the Association of American Geographers. XL (1) 1-38.

Bradley C. and C. Wallis. 1996. Prairie ecosystem management: an Alberta perspective. Published by Prairie Conservation Forum, Occasional Paper No. 2. 29 pp.

Bragg, T. B. 1995. The Physical Environment of Great Plains Grasslands. *The Changing Prairie: North American Grasslands*. New York: Oxford University Press.
Brown, J. K., R. D. Oberheu and C. M. Johnson. 1982. Handbook for inventorying surface Fuels and biomass in the Interior West. USDA For. Ser. Gen. Tech. Rep. INT-129. Intermoun. Forest and Range Experiment Station. 48 pp.
Brown, P. M. and C. H. Sieg. 1999. Historical variability in fire at the ponderosa pine – Northern Great Plains prairie ecotone, southeastern Black Hills, South Dakota. Ecoscience 6(4):539-547.
Brown, James K.; Smith, Jane Kapler, eds. 2000. Wildland fire in ecosystems: effects of fire on Flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Rocky Mountain Research Station. 257 pp.
Catlin, G. 1891. Catlin's Indians. Hubbard Brothers Book Co.
Cawker, K. B. 1983. Fire history and grassland vegetation change: three pollen diagrams from southern British Columbia. Canadian Journal of Botany 61:1126-1139.
Champe, J. L. 1946. Ash Hollow Cave. New Series No. 1. Univ. Nebraska Press, Lincoln.
Clements, F.E. 1916. Plant succssion. Carnegie Institution of Washington – publication 242. Washington, D.C. 512p.
Connelly, J. W., W. J. Arthur and O. D. Markham. 1988. Sage grouse leks on recently disturbed sites. J. Range Manage. 34(2):153-154.
Coppock, D. L., J. K. Detling, J. E. Ellis and M. I. Dyer. 1983. Plant-herbivore interactions in a North American mixed-grass prairie. I. Effects of black-tailed prairie dogs on intra-seasonal aboveground plant biomass and nutrient dynamics and plant diversity. Oecologia 56:1-9.
Dary, D. A. 1974. The buffalo book. Avon Books, New York. 374 p.
Daubenmire, R. 1968. Ecology of fire in grasslands. *in*:Advances in Ecological Research (J. B. Cragg, ed.), Vol. V, pp. 209-266. Academic Press, London.
Daubenmire, R. 1970. Steppe vegetation of Washington. Tech. Bull. 62. Pullman, WA: Washington State University, College of Agriculture, Washington Agri. Exp. Station. 131 pp.
De Jong, T. M. 1975. A comparison of three diversity indices based on their components of richness and evenness. Oikos 26:222-227.
De Velice, R. L., J. Lichthardt and P. S. Bourgeron. 1991. A Preliminary Classification of the Plant Communities of Northeastern Montana. Montana Natural Heritage Program. Helena, MT.
Dittberner, P. L. and M. R. Olson. 1983. The plant information network (PIN) data base: Colorado, Montana, North Dakota, Utah, and Wyoming. FWS/OBS-83/86. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 786 p.
Dix, Ralph L. 1960. The effects of burning on the mulch structure and species composition of grasslands in western North Dakota. Ecology. 41(1): 49-56.
L. C. Eichhorn and R. C. Watts. 1984. Plant succession on burns in the river breaks of central Montana. Proceedings, Montana Academy of Science. 43:21-34.
England, R. E. and A. DeVos. 1967. Influence of animals on pristine conditions on the Canadian grasslands. J. Range Manage. 22:87-94.
Engle, D. M. and P. M. Bultsma. 1984. Burning of northern mixed prairie during drought. Journal of Range Management. 37(5): 398-401.

Frost, C. 1998. Presettlement fire frequency regimes of the United States: A first approximation. Pp. 70-81 *in* Fire in Ecosystem management: Shifting the Paradigm from Suppression to Prescription. Tall Timbers Fire Ecology Conference Proceedings, No. 20. Tall Timbers Research Station, Tallahassee, FL.

Garrison, G.A.; Bjugstad, A.J.; Duncan, D.A.; Lewis, M.E.; Smith, D.R. 1977. Vegetation and environmental features of forest and range ecosystems. *USDA Forest Service Agricultural Handbook No. 475*. p 50-52.

Gartner, F. R. 1975. Final Report: Wind Cave National Park grassland ecology. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station Intermountain Fire Sciences Laboratory, Missoula, MT: 29 p.

Gartner, F. R. and E. M. White. 1986. Fire in the northern Great Plains and its use in management. Pp. 13-21 *In* Proc., Prescribed Fire and Smoke Management Symposium. Feb. 13, 1986 (Kissiminee, Fla.), Soc. Range Manage.

Gould, F. W. 1968. Grass systematics. McGraw-Hill, New York. 382 pp.

Gruell, G. E. 1980a. Fire's influence on wildlife habitat on the Bridger-Teton National Forest, Wyoming. Volume I -- Photographic record and analysis. USDA For. Serv. Res. Pap. INT-235, 207 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Gruell, G. E. 1980b. Fire's influence on wildlife habitat on the Bridger-Teton National Forest, Wyoming. Volume II -- Changes and causes, management implications. USDA For. Serv. Res. Pap. INT-252, 35 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Gruell, G. E., J. K. Brown and C. L. Bushey. 1986. Prescribed fire opportunities in grasslands invaded by Douglas-fir: state-of-the-art guidelines. Gen. Tech. Rep. INT-198, 19 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Heinselman, M. L. 1973. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quartern. Res. 3:329-382.

Higgins, K. F. 1984. Lightning fires in North Dakota Grasslands and in pine-savanna lands of South Dakota and Montana. *Journal of Range Management* 37(2):100-103.

Higgins, K. F. 1986. Interpretation and compendium of historical fire accounts in the northern Great Plains. U.S. Dept. of the Interior, Fish and Wildlife Service Resource Publ. 161. 39 pp.

Holechek, J. L., R. D. Pieper and C. H. Herbel. 1998. Range management - principles and practices. 3rd ed. Prentice-Hall. 542 pp.

Humphrey, R. 1974. Fire in the deserts and desert grassland of N. America. In: Kozlowski, T.; Ahlegren, C. eds. Fire and ecosystems. New York: Academic Press: 365-400.

Hunter, Malcolm L, Jr. 1990. Wildlife, forests, and forestry - Principles of managing forests for biological diversity. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 370 pp.

Johnston, A. 1970. A history of the rangelands of western Canada. J. Range Manage. 23(1):3-8.

Kimmis, J. P. 1987. Forest ecology. McMillian Publishing, New York, New York.

Kucera, C. L. 1981. Grasslands and fire. In *Fire Regimes and Ecosystem Properties,* Honolulu, HI: USDA Forest Service, Washington Office.

Lambeth, R. and M. Hironaka. 1982. Columbia ground squirrel in subalpine forest openings in central Idaho. J. Range Manage. 35(4):493-497.

Larson, F. 1940. The role of the bison in maintaining the short grass plains. Ecology 21(2):113-117.

Lewis, H. T. 1980. Indian fires of spring. Natural History 89(1):76-78, 82-83.

Lewis, H. T. 1982. A time for burning. Occasional Publ. No. 17. Boreal Institute for Northern Studies, Univ. of Alberta. 62 p

Lyon, J. and J. K. Smith, eds. 2000. Wildland fire in ecosystems: effects of fire on fauna. Gen. Tech. Rep. RMRS-GTR-42-vol. 1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 83 pp.

Madden, E. M., A. J. Hansen and R. K. Murphy. 1999. Influence of prescribed fire history on habitat and abundance of passerine birds in Northern Mixed-Grass Prairie. *Canadian Naturalist* 113(4):627-640.

Magurran, A. E. 1988. Ecological diversity and its measurement. Princeton University Press, Princeton.

Marsden, M. A. 1982. A statistical analysis of the frequency of lightning-caused forest fires. *Journal of Environmental Management* 14(2):149-159.

Martin, N. S. 1970. Sagebrush control related to habitat and sage grouse occurrence. J. Wildlife Manage. 34(2):313-320.

McAuliffe, J. R. 1988. Markovian dynamics of simple and complex desert plant communities. American Naturalist 131:459-490.

McNicoll, C. H. 1994. Structural development and classification of western redcedar (*Thuja plicata* Donn.) stands in northwestern Montana. M.S. thesis, University of Montana, Missoula, Montana. 140 pp.

McShane, M. C. and R. H. Sauer. 1985. Comparison of experimental fall burning and clipping on bluebunch wheatgrass. Northwest Science. 59(4): 313-318.

Merriam, C. J. 1902. The prairie dog of the Great Plains. USDA Yearbook 1901. pp. 257-270.

Nash, C. H. and E. A. Johnson. 1996. Synoptic climatology of lightning-caused forest fires in subalpine and boreal forests. *Canadian Journal of Forest Resources* 26:1859-1874.

Nelson, J. G. and R. E. England. 1971. Some comments on the causes and effects of fire in the northern grasslands area of Canada and the nearby United States, 1750-1900. Can. Geogr. 15(4):295-306.

Osborn, B. and P. F. Allan. 1949. Vegetation of an abandoned prairie dog town in tall grass prairie. Ecology 30:315-317.

Owensby, C.E., and K.L. Anderson. 1967. Yield responses to time of burning in the Kansas Flint Hills. Journal of Range Management 20(1): 12-16.

Peet, R. K. 1974. The measurement of species diversity. Annual Review of Ecology and Systematics 5:285-307.

Pechanec, J. F., G. Stewart and J. P. Blaisdell. Sagebrush burning good and bad. Farmers' Bulletin No. 1948. Washington, DC: U.S. Department of Agriculture. 34 p.

Peek, J., R. Riggs and J. Lauer. 1979. Evaluation of fall burning on bighorn sheep winter range. Journal of Range Mgmt. 32(6): 430-432.

Penfound, W.T. and N. W. Kelting. 1950. Some effects of winter burning on moderately grazed pasture. Ecology 31(4):554-560.

Perry, C.A. 1980. Preliminary analysis of regional-precipitation periodicity. *U.S. Geological Survey Water-Resources Investigations* 70-74.

Phillips, W. S. 1962. Fire and vegetation of arid lands. First Annu. Tall Timbers Fire Ecol. Conf. pp 81-93.

Quigley, Thomas M; Haynes, Richard W.; Graham, Russell T.,tech. eds. 1996. Integrated scientific assessment for ecosystem management in the interior Columbia basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-382. Portland, OR: U.S. Department of Agriculature, Forest Service, Pacific Northwest Research Station. 303 pp.

Roe, F. G. 1955. The Indian and the horse. University of Oklahoma Press, Norman.

Roundy. B., J. Young and R. Evans. 1981. Phenology of salt rabbitbrush and greasewood. Weed Science. 29:448-454.

Rowe, J. S. 1969. Lightning fires in Saskatchewan grassland. Canadian Field-Naturalist. 83: 317-324.

Schumacher, C. M. 1974. The Great Plains - wet or dry. J. Soil & Water Cons. 19:156-159.

Scotter, D.R. 1970. Soil temperatures under grass fires. Aust. J. Soil Research 8(3):273-279.

Seton, E. T. 1929. Lives of game animals. Doubleday, Doran & Company, New York.

Shannon, C. E. and W. Wiener. 1949. The mathematical theory of communication. U. of Illinois Press, Urbana, IL.

Shiflet, T.N., ed. 1994. Rangeland cover types of the United States. Denver, CO: Society for Range Management. 152 p.

Sieg, C. H. 1998. *The role of fire in managing for biological diversity on native rangelands of the Northern Great Plains*. GTR RM-GTR-298. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station.

Sims, P.L. 1988. Grasslands. *In*: North American Terrestrial Vegetation. (Barbour, M.G. and W.D. Billings). Cambridge University Press: New York p265-286.

Smith, E.L. 1960. Effects of burning and clipping at various times during wet season on Tropical tallgrass range in northern Australia. Journal of Range Management 13(4)97-103.

Smith, E.L. Soil-vegetation relationships of some Artemisia types in North Park, CO. Fort Collins, CO: Colorado State University. 203 p. Dissertation.

Smith, M, J. Dodd and J. Rodgers. 1985. Prescribed burning on Wyoming rangeland. Bull. 810. Laramie, WY: University of Wyoming Agricultural Extension Service. 25p.

Stewart, O. C. 1953. Why the Great Plains are treeless. Colo. Quart. 2(1):40-50.

Swaine, A. M. 1973. A history of fire and vegetation in north-eastern Minnesota as recorded in lake sediments. Quart. Res. 3:383-396.

Thomas, H.E. 1962. The meteorologic phenomenon of drought in the Southwest. *U.S. Geological Survey Professional Paper 342A*. Washington.

Thompson, S. M. 1990. The initial response of several forage species to prescribed burning in southeastern British Columbia. Vancouver, BC: University of British Columbia. 137 p. Thesis.

Tisdale, E. W. and M. Hironaka. 1981. The sagebrush-grass region: a review of the ecological literature. U. of Idaho Forest, Wildlife and Range Exp. Sta. Bull. No. 33. 31 pp.

United States Dapartment of Agriculture, Forest Service. 1987. Ecosystem classification handbook FSH 12/87 R-1 Supp. 1. Region 1, Missoula, Montana.

Vazquez, A. and J. M. Moreno. 1998. Patterns of lightning-, and people-caused fires in peninsular Spain. *International Journal of Wildland Fire* 8(2):103-115.

Villnow, B. 1995. A rangeland classification system based on vegetation structure. Unpubl. M.S. Thesis, The University of Montana, Missoula MT. 104 pp.

Washington, H. G. 1984. Diversity, biotic and similarity indices. Water Research 18:685-694.

Weaver, J.E. 1954. North American Prairie. Johnsen Publishing: Chicago.

Weaver, J.E. and F. W. Albertson. 1956. Grasslands of the Great Plains. Johnsen Publishing: Chicago.

Wellner, C. A. 1970. Fire history in the northern Rocky Mountains. In The role of fires in the Intermountain West: symposium proceedings. pp 42-64. Intermountain Fire Research Council, Missoula, Montana.

Wells, P.V. 1970. Historical factors controlling vegetational patterns and floristic distribution in the Central Plains Region of North America. In Pleistocene and Recent Environments of the Central Great Plains. D. Wakefield Jr. and K.J. Jones Jr., eds. p 211-221. Special Publication 3. The University Press Kansas, Lawrence.

White, R. S. and P. O. Currie. 1983a. The effects of prescribed burning on silver sagebrush. Journal of Range Management. 36(5): 611-613.

White, R. S. and P. O. Currie. 1983b. Prescribed burning in the Northern Great Plains: yield and cover responses of 3 forage species in the mixed grass prairie. Journal of Range Management. 36(2): 179-183.

Wilson, S. D.and J. M. Shay. 1990. Competition, fire and nutrients in a mixed-grass prairie. Ecology. 71(5): 1959-1967.

Whisenant. S. G. 1990. Postfire population dynamics of Bromus japonicus. American Midland Naturalist. 123:301-308.

Whisenant, S. G. and D. W. Uresk. 1990. Spring burning Japanese brome in a western wheatgrass community. Journal of Range Management. 43(3): 205-208.

Wilson, S. D. and J. M. Shay. 1990. Competition, fire and nutrients in a mixed-grass prairie. Ecology. 71(5): 1959-1967.

Wright, H.A. 1969. Effect of spring burning on tobosa grass. Journal of Range Management 22(6)425-427.

Wright, H.A. 1974. Range burning. Journal of Range Management. 27:5-11.

Wright, H. A. and A. W. Bailey. 1980. Fire ecology and prescribed burning in the Great Plains - a research review. USDA For. Serv. Gen. Tech. Rep. INT-77, 61 p. Intermt. For. and Range Exp. Stn., Ogden, Utah

Wright, H.A.and J. O. Klemmedson. 1965. Effect of fire on bunchgrasses of the sagebrush-grass region in southern Idaho. Ecology. 46(5): 680-688.

Young, J.A. and R. Evans. 1978. Population dynamics after wildfires in sagebrush grasslands. Journal of Range Management. 31(4): 283-289.

Young, J.; Evans, R.; Weaver, R. 1976. Estimating potential down brome competition after wildfires. Journal of Range Mgmt. 29(4): 322-325.

Appendix 1. Data sheet for recording nested microplot data.

Plot ID No __ __ __ Transect No __ No of Species in Transect __ __

Number of Species in Macroplot __ __

GROUND COVER	MICROPLOTS 1	2	3	4	5	
BARE GROUND	__	__	__	__	__	SUM __ __
GRAVEL	__	__	__	__	__	SUM __ __
ROCK	__	__	__	__	__	SUM __ __
MOSS	__	__	__	__	__	SUM __ __
LITTER/DUFF	__	__	__	__	__	SUM __ __
BASAL VEGETATION	__	__	__	__	__	SUM __ __
WOOD	__	__	__	__	__	SUM __ __

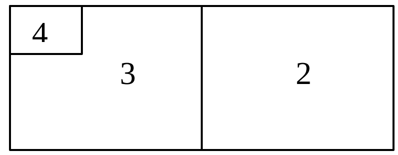
PLANT SPECIES DATA

NO N	LF MHT	NAME	MICROPLOTS 1 FC	2 FC	3 FC	4 FC	5 FC		SRF	FCC		ACC
1	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
2	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
3	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
4	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
5	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
6	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
7	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
8	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
9	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
10	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
11	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
12	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
13	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
14	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
15	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
16	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
17	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __
18	__	__ __ __ __ __ __	__ __	__ __	__ __	__ __	__ __	__ __	__ __ __	__ __	__	__ __ __

Appendix 2. Coding for nested microplot data form.

LF: 1 = Tree 2 = Shrub 3 = Grasses/Grass-Like 4 = Forb

FC: F The smallest field on plot frame that the species in present within.



C Estimate the percentage of canopy coverage of each species and code as shown below.

Code	Range of Class
0	0%
T	0.1 < 1%
P	1 < 5%
1	5 < 15%
2	15 < 25%
3	25 < 35%
4	35 < 45%
5	45 < 55%
6	55 < 65%
7	65 < 75%
8	75 < 85%
9	85 < 95%
F	95 – 100%

SRF (Sum of Rooted Frequency): Add all "F" values for a species.

FCC (Sum of Foliar Canopy Cover): Add mid points of "C" values for a species. For example:
T = 0.5% (round to 1%)
P = 3%
1 = 10%
2 = 20%
3 = 30%
etc.

ACC (Average Canopy Cover): Calculate as the Sum FCC/5 (round to nearest %).

N = number of microplots that species occurs in.

MHT = average height of that species within the plot (ft.)

Appendix 3. Form for recording general macroplot information.

GENERAL PLOT DATA

PlotID ____ Burned (Y/N) ____ APDate _____ AphotoID __________
Legal ID: Town ____ Range ____ Sec ____ QSec ____

GPS

LatNS ____ LatDeg ____ LatMin ____ LatSec ____
LonEW ____ LonDeg ____ LonMin ____ LonSec ____

BurnMo: _____ BurnDay: ______ BurnYr: ______

Horizontal Variation in Tree Canopy Damage by Fire:

__ __ __ __ __
u s c n i

Dead Trees ____ n

Ground Charring __ ___ __ __ __ __
ba dbh u l m d

Crown Scorch (Dead) _____ c

Live Trees __ __ ___
n ba dbh

Crown Scorch (Live) _____ c

Tree Height Class: Live _______ Dead _______

	Date		Time
Discovery	______	Discovery	______
InitAttack	______	InitAttack	______
Controlled	______	Controlled	______
Dect. Out	______	Dect. Out	______

Cause ______
Fire Behavior ________
Fuel Loading Class: _____

Appendix 4. Coding for general macroplot information.

Horizontal Variation in Tree Canopy Damage by Fire:

u = unscorched %
s = scorched %
c = crowned and torched %
n = no prefire canopy %
i = fire intensity class (1-6)

Dead Trees:

n = number in macroplot
c = % of crown scorched

Live Trees:

n = number in macroplot
c = % of crown scorched

Tree Height Class: 10 ft. classes

Ground Charring:

ba = tree basal area
dbh = diameter breast height (inches)
u = % unburned
l = % light charred
m = % moderate charred
d = % deep charred

Cause of Fire:

Fire Behavior:

Fuel Loading Class:

Code	Fuel Loading Class
1	fine, porous and continuous herbaceous fuels of grasslands and grass/shrub types.
2	fine herbaceous fuels with some litter and dead stemwood in habitat types with open shrub and forest overstories.
3	tall, thick graminoid dominated stands.
4	forest or shrub stands with a continuous overstory that contain much flammable woody material.
5	forest or shrub stands with light surface fuels and slightly flammable shrub or woody fuels.
6	open forest with shrubs or shrubs that have moderate amounts of flammable woody material.
7	closed forest stands and understory shrub layer with flammable materials in both layers.
8	closed conifer stands with low flammability and a compact litter layer.
9	closed stands of ponderosa pine with a thick litter layer.

Appendix 5. Plant species encountered within plots. (Note: Scientific names used in this document are those most commonly encountered within the literature and familiar to professional land managers. The most current taxonomy and significant information for each species can be accessed at http://plants.usda.gov.)

	Scientific Name	Common Name
Trees		
	Fraxinus pennsylvanica	green ash
	Juniperus communis	common juniper
	Juniperus scopulorum	Rocky Mountain juniper
	Pinus contorta	lodgepole pine
	Pinus flexilis	limber pine
	Pinus ponderosa	ponderosa pine
	Populus deltoides	eastern cottonwood
	Pseudotsuga menziesii	Douglas-fir
Shrubs		
	Acer glabrum	Rocky Mountain maple
	Arctostaphylos uva-ursi	kinnikinnick
	Artemisia cana	silver sagebrush
	Artemisia filifolia	sand sagebrush
	Artemisia frigida	fringed sage
	Artemisia spinescens	bud sage
	Artemisia tridentata	big sagebrush
	Artemisia spp.	sagebrush
	Atriplex canescens	four-wing saltbush
	Atriplex nuttallii	Nuttall's saltbush
	Atriplex spp.	saltbush
	Berberis repens	Oregon grape
	Chrysothamnus nauseosus	rubber rabbitbrush
	Chrysothamnus viscidiflorus	green rabbitbrush
	Cornus stolonifera	red-ozier dogwood
	Crataegus rotundifolia	hawthorn
	Gutierrezia sarothrae	broom snakeweed
	Juniperus horizontalis	creeping juniper
	Juniperus spp.	Juniper
	Physocarpus malvaceus	ninebark
	Potentilla fruiticosa	shrubby cinquefoil
	Prunus virginiana	chokecherry
	Rhus trilobata	skunkbush sumac
	Ribes aureum	golden currant
	Ribes cereum	wax currant
	Ribes lacustre	brustly black currant
	Ribes oxyacanthoides	northern gooseberry
	Ribes viscosissimun	sticky currant

Appendix 5. Plant species encountered within plots (continued).

Scientific Name	Common Name
Ribes spp.	currant
Rosa arkansana	Arkansas rose
Rosa spp.	Rose
Rubus arizonensis	Arizona dewberry
Salix bebbiana	Bebb willow
Salix spp.	willow
Sarcobatus vermiculatus	black greasewood
Shepherdia canadensis	russet buffaloberry
Spirea betulifolia	white spirea
Symphoricarpos alba	common snowberry
Symphoricarpos occidentalis	western snowberry
Symphoricarpos spp.	snowberry
Grasses and Grass-Like	
Agrostis alba	redtop
Agrostis spp.	bentgrass
Agropyron cristatum	crested wheatgrass
Agropyron dasystachyum	thickspike wheatgrass
Agropyron intermedium	intermediate wheatgrass
Agropyron repens	quackgrass
Agropyron smithii	western wheatgrass
Agropyron spicatum	bluebunch wheatgrass
Agropyron trachycaulum	slender wheatgrass
Agropyron triticeum	annual wheatgrass
Agropyron spp.	wheatgrass
Aristida longiseta	red threeawn
Bouteloua curtipendula	sideoats grama
Bouteloua gracilis	blue grama
Bromus anomalus	Porter brome
Bromus inermis	smooth brome
Bromus japonicus	Japanese brome
Bromus tectorum	cheatgrass
Buchloe dactyloides	buffalograss
Calamovilfa longifolia	prairie sandreed
Calamovilfa montanensis	plains reedgrass
Calamagrostis rubescens	pinegrass
Calamagrostis tweedyi	Tweedy’s reedgrass
Carex bicknellii	Bicknell’s sedge
Carex eleocharis	narrowleaf sedge
Carex filifolia	threadleaf sedge
Carex franklinii	rock dwelling sedge
Carex geyeri	elk sedge

Appendix 5. Plant species encountered within plots (continued).

Scientific Name	Common Name
Carex rostrata	beaked sedge
Carex spp.	sedge
Danthonia spicata	poverty oatgrass
Danthonia spp.	oatgrass
Distichlis stricta	inland saltgrass
Distichlis spp.	saltgrass
Eleocharis spp.	spikerush
Elymus canadensis	Canada wildrye
Elymus spp.	wildrye
Festuca arundinacea	tall fescue
Festuca idahoensis	Idaho fescue
Glyceria septentrionalis	eastern managrass
Hordeum jubatum	foxtail barley
Juncus spp.	rush
Koeleria cristata	prairie Junegrass
Muhlenbergii cuspidata	plains muhly
Muhlenbergii richardsonis	mat muhly
Muhlenbergia sp.	muhly
Oryzopsis hemenoides	Indian ricegrass
Oryzopsis micrantha	littleseed ricegrass
Oryzopsis spp.	ricegrass
Phleum pretense	Timothy
Poa canbyi	Canby's bluegrass
Poa compressa	Canada bluegrass
Poa curtifolia	little mountain bluegrass
Poa nemoralis	woods bluegrass
Poa pratensis	Kentucky bluegrass
Poa sandbergii	Sandberg's bluegrass
Poa trivialis	roughstalk bluegrass
Poa spp.	bluegrass
Schedonnardus paniculatus	tumblegrass
Schizachyrium scoparium	little bluestem
Sitanion hystrix	squirreltail
Sporobolus cryptandrus	sand dropseed
Stipa comata	needle-and-thread grass
Stipa viridula	green needlegrass
Stipa spp.	needlegrass
Vulpia myuros	foxtail fescue
Forbs	
Achillea millefolium	western yarrow
Alchemilla vulgaris	common lady's mantle

Appendix 5. Plant species encountered within plots (continued).

Scientific Name	Common Name
Allionia spp.	four o'clock
Allium textile	textile onion
Androsace septentrionalis	pygmyflower rockjasmine
Anemone multifida	Pacific anemone
Anemone patens	cutleaf anemone
Anemone spp.	anemone
Antennaria rosea	rosy pussytoes
Antennaria umbrinella	umber pussytoes
Antennaria spp.	pussytoes
Apocynum androsaemifolium	spreading dogbane
Argemone intermedia	prickly poppy
Arnica cordifolia	heartleaf arnica
Arnica spp.	arnica
Artemisia campestris	sagewort wormweed
Artemisia dracunculus	tarragon
Artemisia ludoviciana	cudweed sagewort
Asclepius speciosa	showy milkweed
Aster conspicuus	shown aster
Aster hesperius	aster
Aster spp.	aster
Astragalus pectinatus	narrowleaf poisonvetch
Astragalus vexilliflexus	milkvetch
Astragalus spp.	milkvetch
Atriplex triangularis	triangle orache
Balsamorrhiza sagittata	arrowleaf balsamroot
Calystegia sepium	hadge false bindweed
Camelina microcarpa	littlepod falseflax
Campanula aparinoides	bedstraw bellflower
Campanula rotundifolia	bluebell bellflower
Campanula spp.	bellflower
Capsella bursa-pastoris	shepherd's purse
Castilleja hispida	harsh Indian paintbrush
Castilleja spp.	Indian paintbrush
Centaurea repens	Russian knapweed
Cerastium arvense	field chickweed
Chenopodium album	lambs quarters
Chenopodium spp.	goosefoot
Chrysopsis villosa	hairy golden-aster
Cirsium arvense	Canada thistle
Cirsium spp.	thistle
Circaea spp.	enchanter's nightshade
Collinsia spp.	blue-eyed Mary

Appendix 5. Plant species encountered within plots (continued).

Scientific Name	Common Name
Collomia spp.	collomia
Comandra umbellata	pale bastard toadflax
Convolvulus sepium	large bindweed
Convolvulus spp.	bindweed
Corispermum villosum	bugseed
Crepis tectorum	narrowleaf hawksbeard
Cymopterus spp.	parsley
Descuriana sophia	flaxweed tansymustard
Digitalis spp.	foxglove
Echanaceae angustifolia	pale purple coneflower
Epilobium angustifolium	fireweed
Epilobium spp.	fireweed
Equisetum arvense	field horsetail
Erigeron glabellus	smooth fleabane
Erigeron pumilus	shaggy fleabane
Erigeron spp.	fleabane
Escobaria vivipara	spinystar
Euphorbia esula	leafy spurge
Eurotia lanata	winterfat
Fragaria virginiana	strawberry
Fragaria spp.	strawberry
Gaillardia aristata	blanket-flower
Galium boreale	northern bedstraw
Galium triflorum	sweetscented bedstraw
Galium verum	yellow bedstraw
Galium spp.	bedstraw
Gaura coccinea	scarlet beeblossom
Geranium viscossissimum	sticky purple geranium
Geranium spp.	geranium
Geum aleppicum	yellow avens
Geum triflorum	old man's whiskers
Glycyrrhiza lepidota	wild licorice
Grindellia squarosa	curlycup gumweed
Hedysarum sulphurescens	white sweetvetch
Hymenoxys acaulis	stemless hymenoxys
Kocia spp.	kocia
Lactuca pulchella	blue lettuce
Lactuca serriola	prickly lettuce
Lactuca spp.	lettuce
Lappula redowskii	flatspine stickseed
Lathyrus ochroleucus	cream-flowered peavine
Lepidium densiflorum	prairie pepperweed

Appendix 5. Plant species encountered within plots (continued).

Scientific Name	Common Name
Linaria dalmatica	dalmatian toadflax
Linum lewisii	Lewis flax
Linum perenne	prairie flax
Linnaea spp.	twin-flower
Lithospermum arvense	corn gromwell
Lithospermum ruderale	western stoneseed
Lomatium macrocarpum	bigseed biscuitroot
Lupinus sericeus	silky lupine
Lupinus sulphureus	sulfur lupine
Lupinus spp.	lupine
Mamillaria missouriensis	yellow pincushion cactus
Medicago lupulina	black medic
Medicago sativa	alfalfa
Melilotus alba	white sweetclover
M*elilotus officinalis*	yellow sweetclover
Monarda fistulosa	wild bergamot
Monarda spp.	horsemint
Musineon divaricatum	leafy wildparsley
Opuntia fragilis	brittle pricklypear
Opuntia polycantha	plains pricklypear
Opuntia spp.	pricklypear
Osmorhiza chilensis	sweetcicely
Oxytropis sericea	whitepoint locoweed
Penstemon spp.	penstemon
Perideridia gairdneri	Gerdner's yampah
Petalostemon purpurea	purple prairie clover
Phlox caespitosa	tufted phlox
Phlox diffusa	spreading phlox
Phlox hoodii	Hood's phlox
Phlox spp.	phlox
Plantago spp.	plaintain
Potentilla gracilis	graceful cinquefoil
Potentilla pensylvanica	Pennsylvania cinquefoil
Potentilla spp.	potentilla
Ranunculus spp.	buttercup
Ratibida columnifera	upright prairie coneflower
Rumex crispus	curly dock
Selaginella densa	little clubmoss
Senecio spp.	groundsel
Smilacina stellata	starry solomon-plume
Smilax spp.	greenbrier
Solidago missouriensis	prairie goldenrod

Appendix 5. Plant species encountered within plots (continued).

Scientific Name	Common Name
Solidago spathulata	coast goldenrod
Solidago spp.	goldenrod
Sonchus arvensis	perennial sowthistle
Sphaeralcea coccinea	scarlet globemallow
Stachys palustris	swamp hedge-nettle
Taraxacum officinale	dandelion
Thalictrum occidentale	western meadow-rue
Thalictrum venulosum	veiny meadow-rue
Thermopsis rhombifolia	round-leafed thermopsis
Thlaspi arvense	field pennycress
Toxicodendron rydbergii	western poison-ivy
Tragopogon dubius	yellow salsify
Tragopogon spp.	salsify
Trifolium spp.	clover
Urtica dioica	stinging nettle
Verbascum thapsus	flannel mullein
Vicia americana	American vetch
Vicia spp.	vetch
Viola nuttallii	Nuttall's violet
Viola spp.	violet
Xanthium strumarium	common cocklebur
Xanthocephalum sarothrae	broom snakeweed
Yucca glauca	soapweed yucca
Zigadenus elegans	mountain deathcamas
Zigadenus venemosus	meadow deathcamas